Nordas and Gleditsch (2007) find that the links between climate change, national security and armed conflict have increasingly been made by governmental and international organisations in recent years without reference to sufficient empirical evidence. The papers of the special issue highlight two causal links between climate and conflict: fighting over resources, such as food and water, diminished by climate change impacts; and tensions caused by migration of large numbers of people fleeing climate impacts (Barnett & Adger, 2007; Nordas & Gleditsch, 2007; Reuveny, 2007). However, they show little evidence for organised armed conflict but more for unorganised violence. Nordas and Gleditsch (2007) highlight a need for more systematic studies and more sophisticated conflict models that consider both the kinds of violence that could be expected and the links to specific impacts of climate change, both positive and negative as well as likely adaptation measures. There are fewer examples of studies that look at the issue of security or conflict with respect to the impacts of climate change on water resources in international river basins (Gleick, 1988; van der Molen & Hildering, 2005).

This growing body of literature linking climate change impacts to the potential for violent conflict contrasts with much of the literature on international river basins. Wolf (1998) examines historic water conflicts and suggests that there have been few examples of wars over water historically and that international water is more likely to induce cooperation than violent conflict due to a number of factors including the shared interests of riparians, the resilience of institutions where cooperative water regimes have been established and the high economic cost of war compared to the cost of water. This view is supported by a study by Yoffe *et al.* (2003) in which the authors examine the Transboundary Freshwater Dispute of historical incidents over international waters between 1948 and 1999. For the 122 international river basins that were documented, the number of cooperative incidents (67%) was found to far exceed the number of conflictive events (28%).

Forms of conflict and cooperation

As the Yoffee *et al.* (2003) paper shows, cases of both conflict and cooperation over internationally shared water resources have been documented. A number of papers have attempted to theorise and understand conflict and cooperation. In this section we review the literature that describes how both conflict and cooperation over international rivers can take many forms, occur at various scales, over a variety of issues.

Yoffe *et al.* (2003) developed a Water Event Intensity Scale, which draws from the International Cooperation and Conflict Scale of Azar (1980). The scale ranges from extreme conflict at –7, for a formal declaration of war, through to extreme cooperation at 7 for voluntary unification into one nation. In this scale conflictive interactions include hostile verbal expressions (official or unofficial) and hostile diplomatic, economic or military acts. Cooperative interactions include official verbal expressions of support and cultural, scientific, economic, technological, industrial or military support or agreement (Yoffe *et al.*, 2003). This scale is taken up by Zeitoun and Warner (2006), who combine it with the NATO conflict-development scale to produce a Conflict Intensity Frame (shown in Fig. 1) that differentiates between three main categories of conflict: no significant conflict, cold conflict and violent conflict. Zeitoun and Warner (2006) demonstrate how relations between states can undergo various degrees of intensity of conflict over time and that conflict should not just be

understood as violent conflict between nation states: less-intense conflicts are still forms of conflict. Recent theorising on conflict over transboundary water resources by Zeitoun (2007) has expressed the dynamics between states in terms of the securitization of the issue, described as the framing of "the issue in terms of security…. drawing on perceptions of national, local or individual (in)security" (Zeitoun, 2007, p115). The level of securitization ranges from non-politicised (no conflict and some cooperation) through to politicised, securitised and armed (violent conflict). Here, it is the perceptions of states as to how water sharing issues relate to threats to national security that define the level of securitisation.

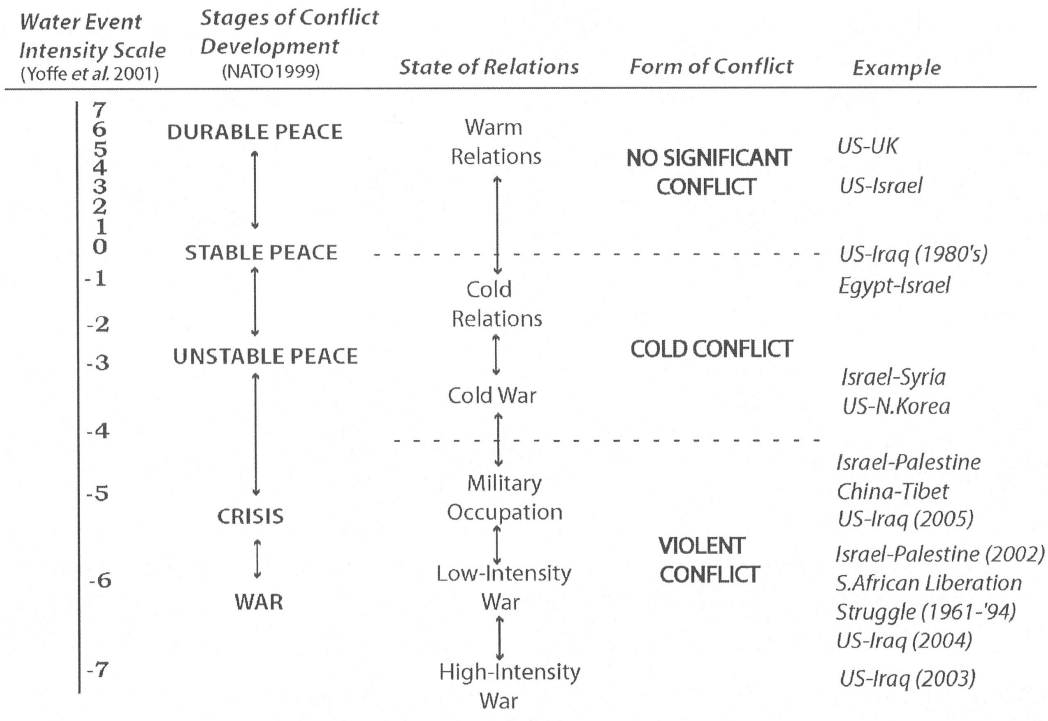

Fig. 1 Conflict Intensity Frame by Zeitoun & Warner (2006)

Until recently cooperation has been less theorised than conflict (Mirumachi, 2007, Allan, personal communication). Kistin (2006) warns against employing a simplistic dichotomy of conflict and cooperation to describe relations between riparian states and that cooperation should not be seen just as the absence of conflict. Mirumachi (2007) develops a typology of levels of cooperation adapted from Tuomela (2000). These are: confrontation of an issue; ad hoc collaboration; technical collaboration; risk-averting cooperation and risk-taking cooperation.

Cooperation over internationally shared water resources can occur through a number of different formal or informal mechanisms. Formal mechanisms include international conventions, bilateral or multilateral treaties or agreements involving some or all riparian states, joint river management institutions and joint projects. Informal mechanisms can include knowledge or data sharing. Formal institutions involved in cooperation in African river basins include institutions of the African Union: the African Ministerial Council on Water (AMCOW); and the New Partnership for Africa's Development (NEPAD) and also the UN Economic Commission for Africa (ECA). There are a number of important regional institutions such as the Southern

African Development Community (SADC) and the East African Community (EAC) that have a remit that includes transboundary resource management amongst other goals of political, economic and environmental cooperation and regional integration (Wirkus & Böge, 2006). In SADC these goals are implemented through the SADC Protocol on Shared Water Resources (Kistin & Ashton, 2008). Several African river basins have a river basin organisation as well as a number of bilateral or multilateral agreements, for example the Senegal, Niger, Lake Chad, Okovango, Limpopo, Orange and Zambezi basins (United Nations Economic Commission for Africa, 2000; Wirkus & Böge, 2006). The Nile Basin does not have a river basin organisation or any agreements involving all riparian countries, although there are a number of bilateral treaties that date back as far as 1891 (United Nations Economic Commission for Africa, 2000). However, there have been a number of cooperative programmes the latest of which is the Nile Basin Initiative started in 1999, which has a number of projects aimed at developing trust amongst stakeholders in the basin and encouraging sustainable development of Nile water resources (Wirkus & Böge, 2006; Nile Basin Initiative, 2007)

Treaties are varied and use a number of different principles, many of which are enshrined in the 1997 Watercourses Convention: universal participation, equitable use, avoiding significant harm, sovereign equality and territorial integrity, information exchange, consultation, prior notification, environmental protection, peaceful dispute resolution (Conca, 2006). However, in a study of the principals incorporated into international river agreements Conca (2006) found that there are tensions between some of the principals, such as those of 'no significant harm' and 'equitable use'. Waterbury (2002) describes how different riparian countries in the Nile basin defend their rights to Nile waters based on one or other, or occasionally both of these two principles. Egypt gives prominence to the principal of significant harm to defend its existing uses of Nile waters, whilst Ethiopia argues for equitable use to allow it to develop its use of Nile water (Waterbury, 2002). Despite these and other impediments to the formation of international agreements in many river basins, Wolf *et al.* (2003) find that co-riparian relations are more cooperative in basins that have treaties and a high density of dam infrastructure than those basins that have a high density of dams but no treaties.

Wolf *et al.* (2003) found that cooperation occurs over a wide range of issues in international river basins including joint management, water quantity, water quality, infrastructure, hydropower and economic development, whilst most conflictive events occur over just two issues: water quantity and infrastructure. In contrast Wolf (2007) describes most water disputes as revolving around three issues: quantity, quality and timing. Emphasis on benefit sharing as a mechanism for cooperative river basin management can lead to a broader range of issues being included in negotiations and agreements between riparians, for example including issues of trade, immigration and environmental protection as well as issues of water use for irrigation, domestic water supply or hydropower generation, for example (Sadoff *et al.*, 2002). For example, projects being planned under the NBI include several joint multi-purpose projects that provide different benefits to several riparian countries including the provision of electricity, flood protection and irrigation (Nile Basin Initiative, 2007).

The scale at which interactions occur is important for understanding conflict and cooperation in international river basins. Whilst extreme conflict (i.e. war) over water, or other renewable resources, is seen as unlikely at the international scale by Wolf (1998), there is evidence for regional disputes over water and other natural resources

(Homer-Dixon, 1994; Wolf, 1998; Meier *et al.*, 2007). Wolf finds that "geographic scale and intensity of conflict are inversely related" (1998, p261) and asserts that there is the highest potential for violence at the regional scale (within-countries), whilst there is little potential for violence between states (Wolf, 2007). Much of the literature on climate and conflict referred to at the start of this section presents examples of conflict at the regional scale (Meier *et al.*, 2007; Raleigh & Urdal, 2007).

Whilst nation states are the key stakeholders considered in the international relations approach to the study of international rivers, a number of different stakeholders are involved in these interactions, including the executive authorities and policy making elites of the riparian states at national and local government level, and non-state actors, such as international donor institutions, multi-national firms, civil society and the environment (Waterbury, 2002; Wolf *et al.*, 2003; Furlong, 2006). Engagement with different stakeholders can be important for the public acceptance of proposed measures of cooperation (Huisman *et al.*, 2000).

The benefits of cooperation and the disadvantages of conflict

Cooperation in international river basins is seen as desirable and to yield benefits (Sadoff & Grey, 2002; Waterbury, 2002; United Nations Development Programme, 2006). Sadoff and Grey (2002) describe four types of benefits. The first of these are described as benefits granted *to the river* by cooperative basin-wide environmental management, for example improvements in water quality, maintenance of biodiversity and conservation of wetlands, floodplains and groundwater recharge areas. Secondly they describe potential benefits *from the river*, for example hydropower, irrigation, flood and drought management and navigation. The third type of proposed benefits are benefits *because of the river*, for example reduced risk of conflict between riparian nations and increased food and energy security, and fourthly, benefits *beyond the river* such as integration of regional infrastructure, markets and trade. Sadoff and Grey (2002) suggest that there are costs to non-cooperation as well as to cooperation and that depending on the particular circumstance the scale of benefits may or may not outweigh the costs of cooperation. In the absence of strong cooperation, Zeitoun and Warner (2006) assert that even the varying intensities of conflict that commonly exist but fall short of violent conflict or war have negative consequences on the less powerful riparians.

Conditions, barriers and limitations of cooperation

Despite the benefits proposed from cooperation over shared water resources in international river basins the literature cites a number of conditions necessary for and barriers or limitations to cooperation that can be political, institutional or geographical.

Wolf (1998) refers to geographical determinants of conflict and cooperation by suggesting that conflict is more likely where the downstream nation is the hegemon, or nation with most power, and upstream countries launch projects that reduce water quantity or quality. Other factors thought to have influence on whether cooperation or conflict occurs include the hydroclimatology, particularly the nature of variability and extremes, the institutional capacity to absorb change and the political situation in the riparian countries, in particular whether countries are democracies or not (Wolf *et al.*,

2003; Yoffe *et al.*, 2003). Van der Zaag and Savenije (2000) describe the foundation for balanced and equitable sharing of international water resources as IWRM, supported by three pillars: technical cooperation; an enabling political environment; and adequate institutions. Wolf (1998) suggests that riparians need incentives for cooperation, such as strong third party encouragement and extensive funding from the international community.

The political aspects of transboundary relations are examined by Zeitoun and Warner (2006) and Zeitoun and Allan (2008). They develop a framework of hydro-hegemony, in which the key factor determining the outcome of competition for water in international river basins is the relative power wielded by each riparian. They also find that the upstream/downstream positions of the riparians and their potential to exploit water through infrastructure and technical capacity also play a role in determining outcomes. They argue that the hydro-hegemon, the riparian state with most power, determines the nature of interactions over water resources and whether they are cooperative or competitive and whether benefits from the river reach weaker riparians or not (Zeitoun & Warner, 2006). Recent research in the Nile basin applying the hydro-hegemony framework has investigated the 'counter-hegemonic' strategies used by weaker riparian states, such as Ethiopia, to oppose or challenge the status-quo maintained by the hydro-hegemon (Egypt, Cascao, 2008).

The idea that cooperation is inherently good has been questioned by (Kistin, 2006; Kistin & Phillips, 2007), who ask what constitutes effective cooperation? They find that many of the existing arrangements for cooperation in international agreements are flawed because of factors relating to inclusivity, data quality and transparency, flexibility, equitability, environmental sustainability, implementation and enforcement. An example of limitations to cooperation related to flexibility is provided by Fischhendler (2004), who finds that treaties often lack mechanisms to deal with climate variability and that this impedes the ability of treaties and institutions to manage a crisis, such as a drought situation. Drieschova *et al.* (2008), in a review of 50 agreements for international river basins, find that there are tradeoffs between flexibility in treaties and the enforceability of the agreements. Nevertheless, there are some documented examples of cooperation that incorporates flexibility in response to water variability for African river basins. For example, Conway (2005) describes a treaty for the Nile Basin that has a mechanism to adapt to water deficits during drought situations. Similarly, Kistin and Ashton (2008) find a variety of flexibility mechanisms in formal agreements in the Orange basin in Southern Africa that provide for adaptive capacity in transboundary water management. However, Kistin and Phillips (2007) conclude that not all cooperation produces positive outcomes and that where circumstances are asymmetrical, inequitable or unsustainable outcomes may result from cooperation.

In the context of climate change an important question is whether barriers to cooperation can be overcome following an emergency such as an extreme climate event that has an impact on one or more country in a international river basin. Huisman et al. (2000) in a study of European international river basins found that disasters with international impacts can lead to a breakthrough that improves transboundary cooperation. However, Waterbury (2002) suggests that "crisis in the quantity or quality of supply may drive users toward cooperation or, alternatively to conflict" (page 166).

CONCLUSIONS

In this paper we have reviewed evidence for climate change and its possible impacts on water resources in Africa, the challenges of adaptation to climate change impacts on water resources, particularly in international river basins and the role of conflict and cooperation in water resource management in international river basins.

Africa faces significant challenges to water resources management in the form of high variability and regional scarcity, set within the context of generally weak institutional capacity. Management is further challenged by the transboundary nature of many of its river basins. Climate change, despite uncertainty about the detail of its impacts on water resources, is likely to exacerbate many of these challenges. Empirical and modelling analyses demonstrate that river flows are highly sensitive to climate perturbations. Studies that project changes in average surface runoff conditions from climate and hydrological models show increases in runoff during the 21st Century for some regions of Africa, for example in the West African river basins of the Niger and Volta, whilst in central and East Africa the studies disagree on the direction and magnitude of change. In Southern Africa, which is already a region prone to water scarcity, the model projections show decreasing surface runoff in the future. However, these projections are uncertain and for the majority of river basins, economically and demographically driven growth in demand is expected to outweigh climate-induced changes.

Globally, adaptation in the water sector is beginning to emerge although evidence suggests this is primarily in the form of building adaptive capacity and no regrets type activities in response to other factors in addition to climate. The combination of uncertainty and the need to consider non-climate factors in water resource management is leading to a greater emphasis on flexibility, adaptive management and responses that are robust to uncertainty (for example, Frederick *et al.*, 1997; Stakhiv, 1998; Pahl-Wostl *et al.*, 2005; Dessai & Hulme, 2007). The nuances of such approaches and their requirements for fairly sophisticated levels of policy and institutional capacity means their application in an African context will require careful consideration and good understanding of local complexities.

The transboundary nature of the resource and its role in these processes is poorly understood, as is the role that climate extremes and future climate change play. International river basins and their riparian states differ in their capacity to adapt to changing water availability and demand and extreme climate events, as indicated by their differing economic resources, social vulnerability, institutional arrangements and the degree of inequality within the basin. This raises concerns that one country's adaptation may cause a negative impact on another country's ability to adapt and emphasises the need for cooperative responses to climate change and other of drivers of change in water resources. Our review highlights several features of cooperation in transboundary water resource management that are relevant to climate change adaptation. Cooperation is seen to have several types of benefits including benefits for water resource management and potentially benefits for adaptation, but there are costs to cooperation as well as costs of non-cooperation (Sadoff & Grey, 2002). Cooperation or conflict occurs at varying intensities and geographic scales in international river basins over a number of issues and through both formal and informal mechanisms. Cooperation should not just be seen as the absence of conflict (Yoffe *et al.*, 2003; Kistin, 2006; Zeitoun & Warner, 2006). The power relations between states sharing a river basin have a major influence on the nature of

interactions between states and the outcome of competition for water resources (Zeitoun & Warner, 2006). In addition, the perceptions of states as to how water sharing issues relate to threats to national security define the level of securitisation (Zeitoun, 2007) and this in turn influences interactions. Crisis situations or international emergencies, for example due to flooding or drought, have the potential to either prompt enhanced cooperation or, alternatively, they may exacerbate conflict (Huisman *et al.*, 2000; Waterbury, 2002).

Following on from this review we suggest an agenda for further research on adaptation to climate change in African international river basins. Research is needed to identify current adaptations occurring at both national and international scales and what factors are driving these adaptations. The range of water scarcity conditions and measures of adaptive capacity between basins in Africa suggest that different combinations of adaptation options will need to be considered, including *inter alia*, storage, supply/demand management and the potential for intra-basin virtual water transfers. The specific physical, economic and political situations in African international basins also deserve more attention, in particular, whether and in what way they are unique and how they mediate processes of adaptation and cooperation. For both African and other international basins there is a need to review the appropriateness of existing institutional structures and frameworks for treaties in the context of climate change and research new approaches that are better suited to non-stationary hydrological conditions.

There is some evidence that cooperative mechanisms may enhance water resource management in international river basins and may therefore also enhance adaptation to climate variability, climate change and other pressures on water. However, cooperation needs to be examined carefully for how it contributes to adaptation to climate change for different states in river basins. It can not be assumed that cooperation will facilitate adaptation for all riparian countries due to asymmetric power relations between countries. Research is needed to examine the factors and processes that are important for cooperation to lead to positive adaptation outcomes and increasing adaptive capacity of water management institutions. For example, is the threat of climate change or experiences of past climatic disasters providing an impetus for cooperation or perhaps a justification for counter-hegemony strategies by weaker riparian states? The role of specific extreme climate events in triggering cooperation or conflict could be examined for cases in African international river basins. In addition, where indicators of conflict do exist between riparian states, does this conflict present a limit to adaptation to climate extremes and future climate change?

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