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Key words: Climate change impacts, Nile River, resource conflict, societal stability, security, water agreement.

Abstract

To enhance the understanding of potential security risks posed by climate change, a framework for the integrated assessment of the Nile River basin is developed. This region can be considered a climate security hot spot, as it is expected that this region will be severely affected by global warming. Rising temperatures and changing precipitation patterns exacerbate already existing problems of desertification, water scarcity, and food production. The aim of this assessment is to identify the key links between climate change and security and their potential for inducing resource conflicts and societal instabilities. Based on data of key countries in the Nile River Basin regarding various economic, environmental, developmental, and political dimensions, an analysis of the potential regional security implications and conflicts is conducted. In this context, a system framework is introduced to outline the complex interactions between the most important variables of the climate system and fundamental socio-economic quantities in the upstream and downstream countries of this region. Using the water allocation of the Nile River as an example, we assess the potential impact of climate change on the allocation schemes between the countries and whether possible changes in these schemes lead to more cooperation between the riparian countries or destabilize the Nile River basin instead. In the past, Egypt has established itself as a water hegemon that controls a majority of the water

resources of the region. This status has been recently challenged by developments and alliances of the upstream countries, increasing the tension between Egypt and some of its neighbors. Unfavorable shifts in precipitation patterns can augment the pressure on the downstream countries, causing them to shift towards strategies that are based on threats rather than on cooperation. A computational modeling environment is used to assess the dynamic interactions between countries which invest into different action paths to improve water availability, considering recent developments and different future scenarios.

Introduction

In recent years, an increasing attention has been paid to the potential security risks and conflicts associated with global warming (Campbell et al, 2007; CNA, 2007; Maas & Tänzler, 2009; WBGU, 2008). Since simple assertions of "climate wars" did not find empirical grounding, it became increasingly clear that the interconnections between environmental conditions, resource scarcity, human wellbeing and possible societal instability are complex and difficult to assess quantitatively. Thus, previous research on the link between climate change and conflict has so far been inconclusive (Barnett, 2003; Barnett & Adger, 2007; Nordås & Gleditsch, 2007; Scheffran et al, forthcoming). While this may be partly due to the fact that climate change is still in its early stages, it may well be possible that with an increasing magnitude in the next decades the climate signal may become more visible in the social sphere and conflicts could emerge on a larger scale.

A key question in this regard is not only how vulnerable human societies are but also how they respond to the risks and challenges posed by global warming, which depends on their capabilities to mitigate and adapt to the problem. It is a reasonable assumption that societies can adapt to some degree of climate change. However, if the speed and magnitude of change exceed the adaptive capacities, this could possibly destabilize social structures and generate a substantial conflict potential. It is difficult to test this hypothesis because adaptive capacities are not fixed but can grow with the challenge. In addition, actors could contest each others capabilities in conflict or merge them through cooperation.[1] Here it matters that countries and regions can be affected quite unevenly by climate risk and have different adaptive capacities. These asymmetries can further contribute to the conflict potential as some actors could use their power to avoid risks or gain benefits at the cost of others who could feel pressed to defend their interests by non-conventional means, including violence.

The implications for human societies can be expected to be greatest in regions with large population densities and a critical reliance on a functioning environment to maintain human welfare (IPCC, 2007). One such region is the Nile River basin in Northeast Africa. It is an important lifeline, as more than one fifth of the African population lives within this river basin (World Bank, 2010).

[1] Conflict is understood here as a social interaction in which actors pursue incompatible goals and use their capabilities in a way that is harmful to others. In cooperation their actions are mutually beneficial.

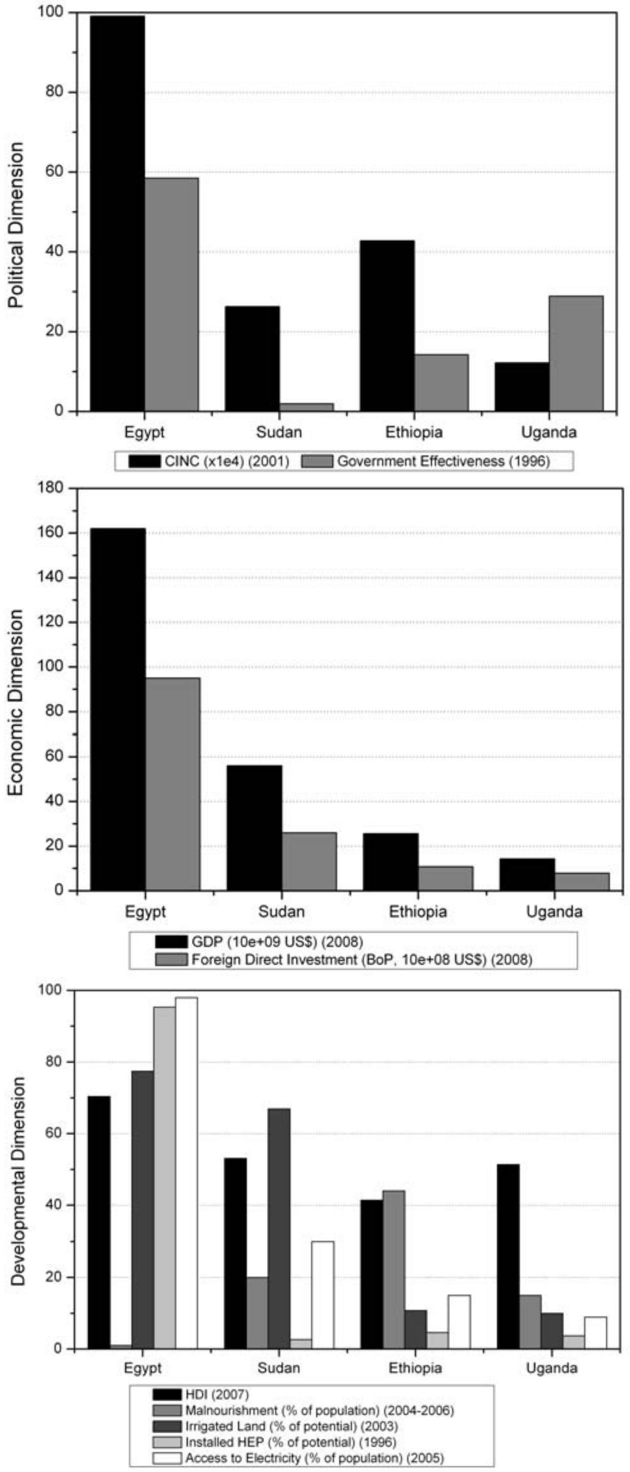

Figure 1a-c: Asymmetries supporting Egypt's status as hydro-hegemon in the Nile Basin. The term CINC denotes the Composite Index of National Capability (Amer et al, 2005; CIA, 2010; FAO, 2010a; FAO, 2010c; Kaufmann, Kraay & Mastruzzi, 2008; Pacific Institute, 1999; Singer, 2005; UNEP, 2009; World Bank, 2010; World Resource Institute, 2010)

The population in the riparian countries continues to grow, augmenting the pressure imposed on the Nile River as the basic water resource. Studies on the implications of climate change on the Nile River indicate that the water resources in this part of the world are highly sensitive to possible changes in climatic conditions (Beyene, Lettenmaier & Kabat, 2009; Conway et al, 2007). While it is not clear in which way the magnitude of precipitation will change in the long run (Elshamy, Seierstadt & Sorteberg, 2009), the irregularity and strength of extreme events is expected to increase. Furthermore, the temperature development is likely to lead to higher evaporation and water demand (Conway, 2005). The uncertainty in future water supply could have profound impacts on economic activities, food security, energy supply and environmental quality in Northeastern Africa (Hulme et al, 2005; Yates & Strzepek, 1998) and thus on societal stability in general. Increased water scarcity requires societies to adapt to the altered conditions, for which it is necessary to develop appropriate capabilities and management schemes (Iglesias et al, 2007).

This paper explores the possible implications of changes in water availability in the Nile River basin as a consequence of climate change. In particular, we focus on water allocation schemes and assess whether climate change actually has an influence on the distribution patterns among the countries. Furthermore, it is discussed whether the strategies followed by the individual countries to acquire their desired water availabilities change depending on the future development of precipitation patterns and how such shifts affect the overall stability in the Nile River basin.

Even though there are ten riparian countries in the Nile River basin, this study focuses only on four of them (Egypt, Sudan, Ethiopia, and Uganda), as these are the most important actors involved in the allocation of the Nile water. The next section looks at the role of Egypt in the Nile River basin with its dependence on upstream water and its very limited amount of potentially arable farm land. On the other hand, it is the dominant industrial power in the region, enabling it to exert its power as a hydro-hegemon to satisfy its water needs, a status that is increasingly contested.

The subsequent section focuses on how the Nile River basin may be affected by climate change and what the connections are between the availability of water and conflicts in this region of Northern Africa. Afterwards, an integrated assessment model is presented that can be used to look at the possible competition of water allocation schemes between the key riparian countries. Some results of model simulations for different scenarios of climate change are presented. The final section of this paper discusses the results and draws some general conclusions.

The water conflict in the Nile Basin

Relevance of the Nile River

The Nile River basin is of vital importance to the African continent and its use has a long cultural heritage over several millennia. Supposedly the longest river in the world, it flows through ten countries before reaching the Eastern Mediterranean Sea. The drainage basin comprises an area of more than 3.3 million km^2 (Beyene, Lettenmaier & Kabat, 2009), which is approximately one tenth the size of the African continent.

The main tributaries are the Blue Nile, which originates in the Ethiopian Highlands, and the White Nile that is fed by the waters from Lake Victoria. There is considerable evaporation in the swamps of southern Sudan that decreases the available water further downstream to a significant extent, reducing the relative importance of the White Nile as a main tributary. While the water supply is obviously greatest in the upstream countries, especially in Ethiopia, the demand for water from the Nile is largest in the downstream countries Egypt and Sudan. This imbalance generates a conflict potential that requires joint efforts to manage the water resources.

Inequality and hegemony in the Nile basin

The relations between the countries of the Nile Basin are characterized by large inequalities between them. Egypt clearly possesses the dominating economic and political power in the region, making the country a de-facto hegemon. How this affects water distribution is discussed in the theoretical framework of hydro-hegemony (Zeitoun & Warner, 2006), which is supported by empirical data. According to their definition, hydro-hegemony in a transboundary river basin rests on three pillars: riparian position, exploitation potential, and power. Here, power is understood to include hard power in the political, economic and military spheres, as well as soft power, which, in this respect, means bargaining and ideational power.

With respect to riparian position, the advantage is clearly with the upstream states Ethiopia and Uganda. In the areas of hard power and, in relation, exploitation potential, the Nile Basin is characterized by large asymmetries between the riparian countries. Following Allan (2009), we use selected empirical indicators to show these asymmetries in three main areas of comparison: economy, politics, and development as proxy for exploitation power and potential. Egypt clearly dominates in all three areas (Figure 1). Egypt also has the highest degree of exploitation of its potentials in the areas of irrigation and installed hydroelectric power (HEP). While the other countries have large potentials in these two areas as well (specifically Sudan for irrigation and Ethiopia for HEP (Amer et al, 2005)), they have not been able to significantly exploit this potential until now.

In terms of the determinants of hydro-hegemony, Egypt therefore dominates in the categories of hard power and actual exploitation. This dominance is partly related to the extensive external support Egypt enjoyed due to its strategic position during the colonial era from the colonial power Great Britain and during the cold war from varying allies (first the Soviet Union, enabling the construction of the Aswan High Dam, and after 1971 the USA (Waterbury, 2002)). This support led to agreements on the use of the Nile waters in 1929 and 1959. In these contracts, Egypt secured the recognition of its ‘natural rights’ to the Nile, authority to supervise any Nile-related projects in the entire basin, and access to around 75% of the Nile waters (Shapland, 1997).

This historical success has enabled Egyptian dominance also in terms of soft, specifically bargaining power. It bases its position on the international water law principles of ”historic rights” and ”avoid significant harm”, and has managed to make this the defining factor of the basin discourse until the 1990s (Cascão, 2009). Egypt’s policy has successfully prevented the upstream nations from developing their water sector by ensuring that its veto power as a downstream nation is recognized by international funding organizations like the World Bank (Waterbury, 2002)[2]. The asymmetry has been reinforced by the long-term weakness of the upstream states, caused by armed conflicts, political instability and low development (Cascão, 2009). Accordingly, Egypt has managed to be in ‘control of the rules of the game’ (Zeitoun & Warner, 2006).

Finally, Egypt has also historically dominated with respect to ideational power. By securitizing the water resources, it has highlighted its own position and turned the

[2] The World Bank does not fund water-related projects without approval by all riparian states (World Bank, 1994).

focus away from the needs of the upstream states (Cascão, 2009). The latter were not able to practically challenge this strategy, despite many formal statements made especially by the Ethiopian government, reiterating its right to use and develop the waters of the Nile[3].

In the framework of hydro-hegemony theory Egypt therefore enjoys historical domination in two out of three dimensions: power (in all its aspects), the most important determinant (Zeitoun & Warner, 2006), and resource exploitation. With these it successfully managed to more than outweigh its disadvantage from its downstream position. Egypt's control of 75% of the Nile water and its success in preventing water development in the upstream states makes it a dominant hydro-hegemon.

Shift to a contested hydro-hegemony

In the past two decades, Egypt's hegemony in the Nile River basin has become increasingly challenged by the upstream states. This is due to a combination of increasing upstream need for development of the water resources and an increasing capacity to do so. The need stems from an increasing population pressure and increasing demand for water and food. Consequently, the upstream countries desire to develop their irrigation potential. Figure 2 illustrates the expected increasing water scarcity in all basin states based on projections of population growth. In that situation, development is imperative, since a higher degree of development increases the ability to cope with the problem. Figure 3 compares hydrological water scarcity, the availability of water per person, to social water scarcity as defined by Ohlsson (2000). Social water scarcity takes into account the level of development by incorporating the Human Development Index[4]. While Egypt as a highly developed state can remedy its large level of hydrological water scarcity, Ethiopia suffers from increased stress levels in terms of social water scarcity. This is exacerbated by population growth. Finally, increasing development enhances the demand for energy, further enhancing the need to develop their large HEP potential.

The increased capacity is mainly due to improvements in the economic sector (World Bank, 2010). All upstream states have seen large levels of economic growth since the mid-1980s, even surpassing that of Egypt[5]. Despite its non-oil economy, Ethiopia has the strongest GDP growth rates of Africa (Tekle, 2010). Also, levels of foreign direct investment and development aid for the upstream countries went up in the last two decades. Especially Sudan attracts more foreign investment, largely due to the exploitation of its oil, while investment is somewhat erratic in Ethiopia and still substantially lower in the other upstream states than in Egypt. Ethiopia receives the highest development assistance, while this has decreased noticeably for Egypt since the beginning of the 1990s. Given the vast differences in electricity consumption noted above, this is particularly difficult for Ethiopia, which historically imported energy and suffers from recurring electricity shortages (Addis Fortune, 2010).

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[3] An example is the 1956 declaration that Ethiopia "reserved its right to utilize the water resources of the Nile for the benefit of its people whatever might be the measure of utilization of such waters sought by riparian states" (Collins, 1990).

[4] The Social Water Scarcity Index is calculated from the Hydrological Water Scarcity Index (defined as hundreds of people sharing 1 million m^3 of water) and the Human Development Index as SWSI=HWSI/HDI*0.5 (0.5 is a scale factor to fit the SWSI on the Falkenmark scale).

[5] GDP of Egypt is still an order of magnitude higher than that of the upstream states – in 2008 162 bio US$ compared to 26 bio in Ethiopia, 56 bio in Sudan and only 14 bio in Uganda (World Bank, 2010).

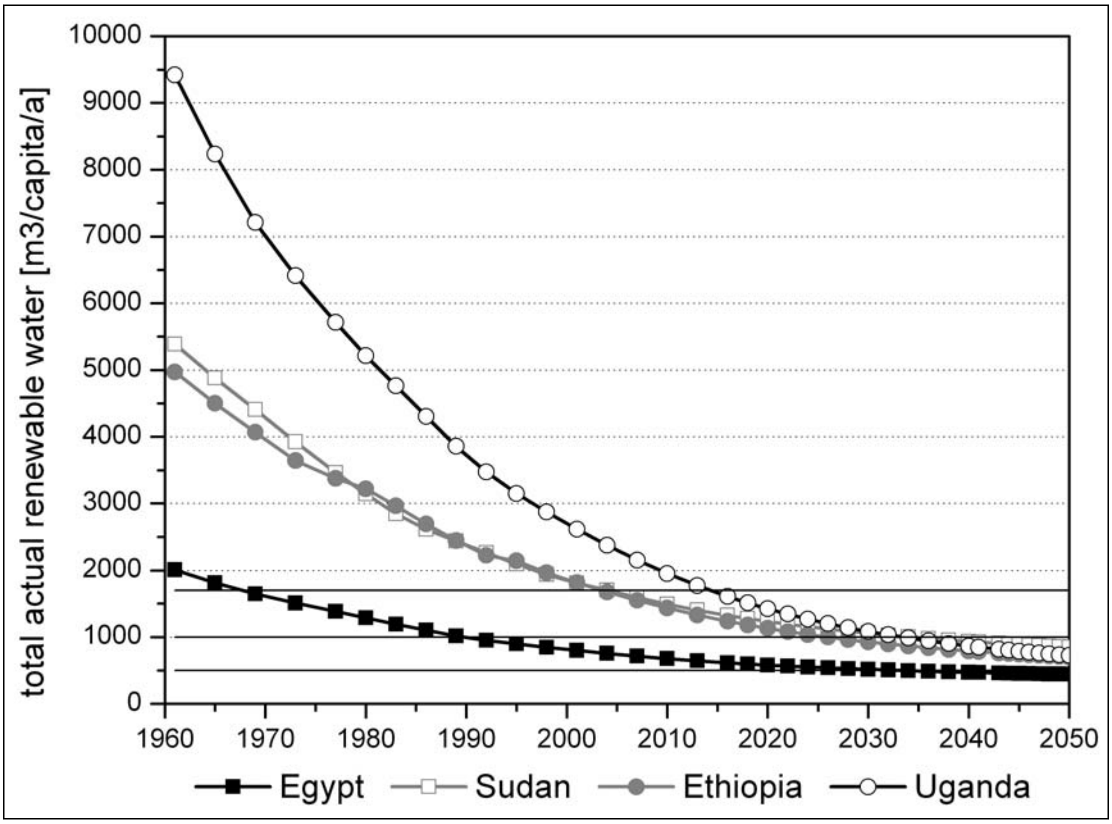

Figure 2: The actual renewable water resources for the four main Nile River basin states projected into the future. The thicker horizontal lines indicate the Falkenmark scale for water scarcity. Falkenmark (1989) classifies countries according to their availability of renewable water per capita in *relative sufficient* (>1700 m^3/capita/a), *stressed* (>1000 m^3/capita/a), *scarce* (>500 m^3/capita/a) and *severely scarce* (< 500 m^3/capita/a). Data sources: (FAO, 2010a; FAO, 2010b)

While the upstream states are still far from being on par with Egypt in the realm of economic power, the growth enables them to implement water development projects without outside funding. An example is the recently inaugurated Tana Beles Dam in Ethiopia, which was largely funded by an investment of the Ethiopian government (Ethiopian News, 2010b). Ethiopia is also investing in a system of microdams for irrigation needs of small farmers (Waterbury & Whittington, 1998). The upstream countries are additionally strengthened by the presence of new actors in the region (such as China and to some extent the Gulf countries), which helps to overcome the blockage of international funding from the traditional funding agencies like the World Bank by an Egyptian veto. China is investing heavily in all regions of Africa and is willing to finance large-scale infrastructure projects such as dams without being overly concerned with environmental issues or international water regulations (Cascão, 2009). In Sudan, China is involved in two dam projects, in Ethiopia in two with interest in a third, and in Uganda in one (International Rivers, 2010). The Gulf States are attempting to improve their food security by buying or leasing land outside of their territory, sometimes called “land grabbing” (Cotula et al, 2009). They therefore have a special interest in Sudan because of its large amount of potentially arable farm land, and they especially support irrigation schemes (Cascão, 2009).

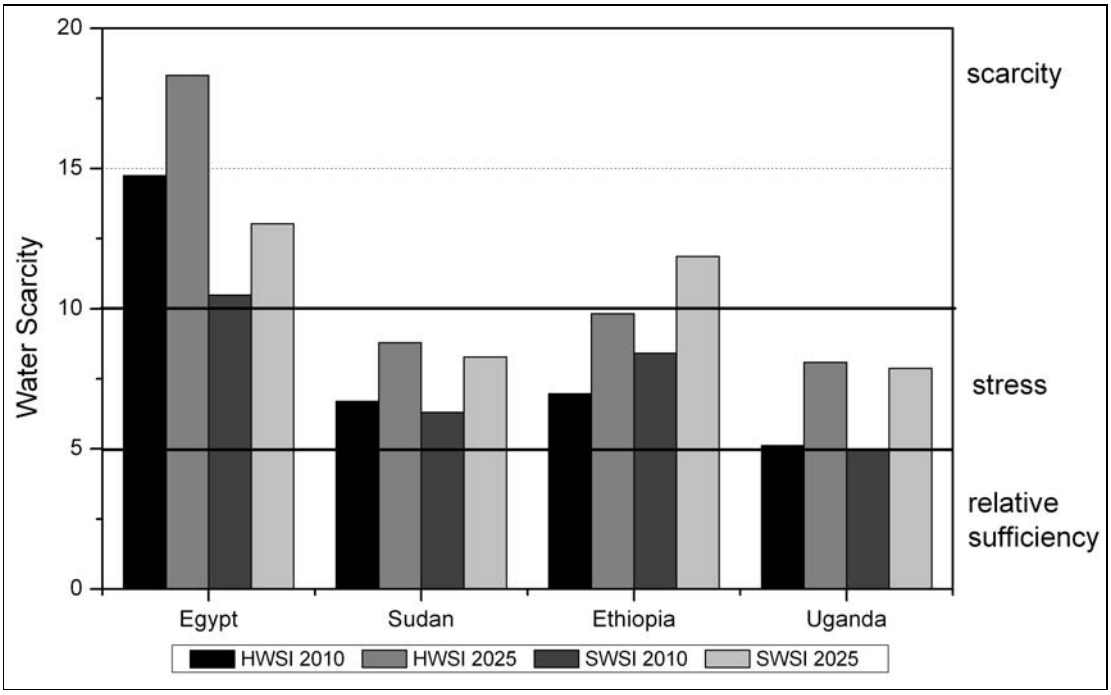

Figure 3: Comparison of hydrological water scarcity (HWSI) with social water scarcity (SWSI). The dark lines indicate the classification according to the Falkenmark water stress index (cf. Fig. 2). While water scarcity measured with this indicator increases in the future due to population growth, the adaptive capabilities are illustrated in the SWSI and put water scarcity into a wider perspective. The predictions for 2025 are based on population predictions with fixed available water and Human Development Index. Data sources: (FAO, 2010a; UNEP, 2009; UNPD, 2008)

In the context of hydro-hegemony, the upstream states clearly gain in economic power and exploitation potential, which translates into an increased potential to use the bargaining power they have due to their upstream position (Cascão, 2009). This challenges Egypt and increasingly transforms the basin from a dominant to a contested hydro-hegemony. The main goal of the upstream states in this challenge is to change the status quo by reallocating water rights according to the ”equitable use” principle, and by abolishing the Egyptian veto on upstream projects. While the improvements discussed above are also true for Sudan, it so far maintains its alliance with Egypt (Zeitoun & Mirumachi, 2008).

A cautionary note on political stability

Often a decrease in armed conflicts in the Nile River basin as well as an increase in political stability is mentioned in the literature in connection with recent economic improvements. However, this is not strictly supported by the data. While the number of wars has decreased in the basin, minor armed conflicts still persist, and the inclusion of non-state violence would make this picture more troubling (Fig. 4). The Ethiopian-Eritrean war in 1998-2000 was costly and peace is very insecure. The situation in Sudan is highly unstable as well, with several areas of armed conflict. Political stability has been a problem in the past (Fig. 5), as it has been consistently low, and Ethiopia has even experienced a significant drop in the political stability index.

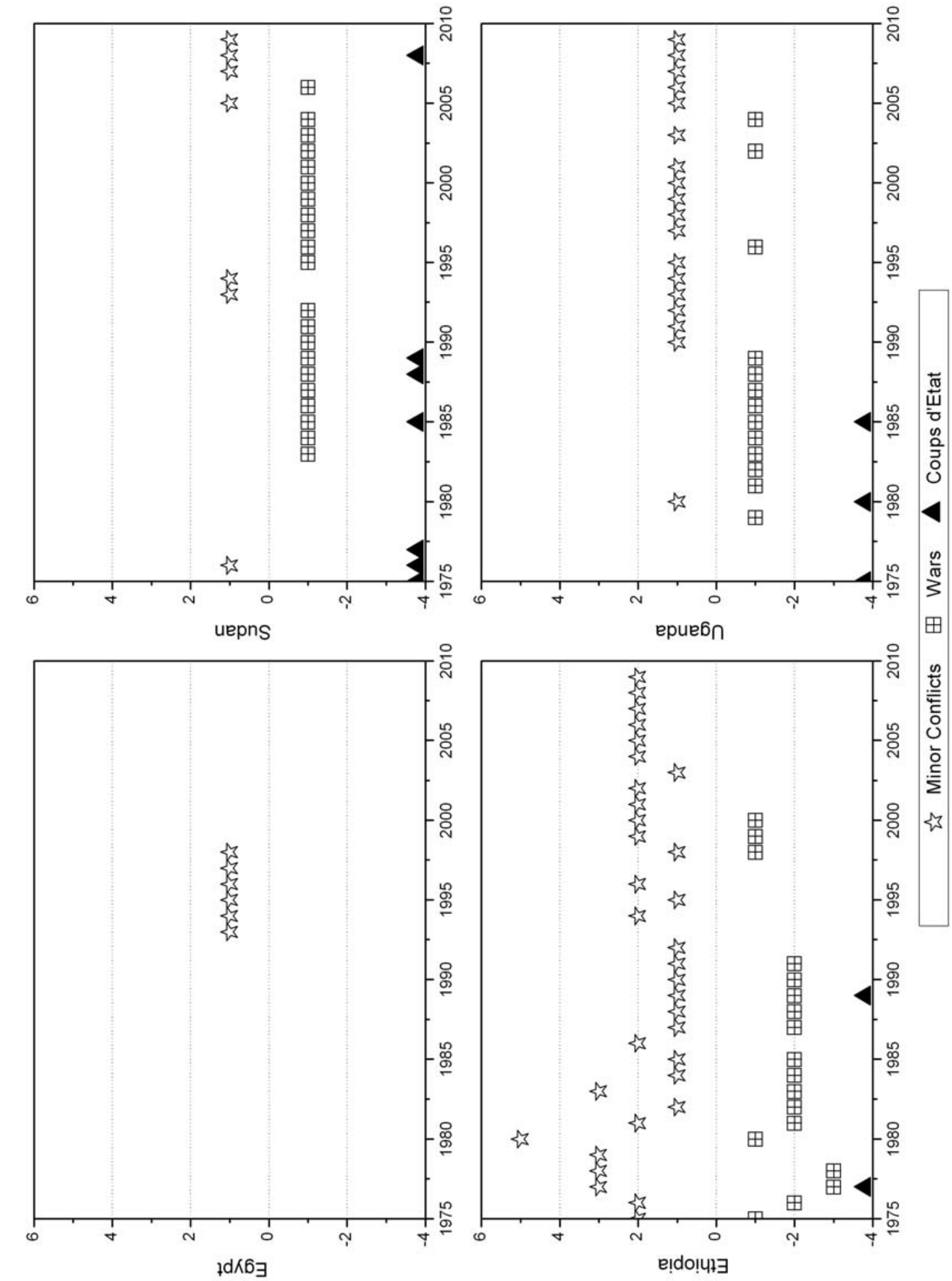

Figure 4: The number of wars, minor armed conflicts and coups d'état 1975 – 2009. The latter only includes successful and attempted coups. (Data source: Center for Systemic Peace 2010, Uppsala Conflict Data Program 2010).

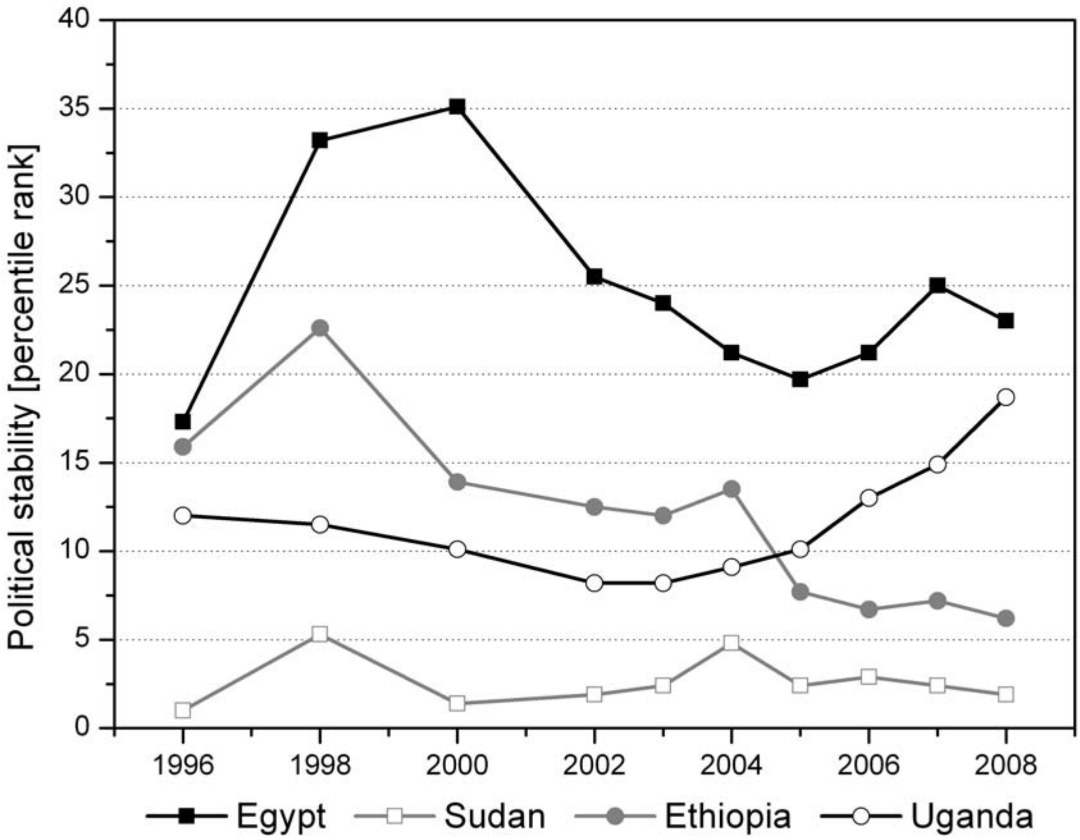

Figure 5: Political stability measured as percentile rank (Data source: Worldwide Governance Indicators 2010).

However, one indicator supporting some degree of stability is government effectiveness[6]. This index considerably improved for Ethiopia in recent years and fluctuated around an average level for the other three countries (Fig. 6). While coups d'état were still prevalent in the 1970s (see black triangles in Fig. 4), Ethiopia and Uganda have not experienced one since the 1980s, and the recent one in Sudan seems to have been an isolated event. The fact that Egypt has experienced its last coup in 1952 is another factor pointing to its political power. Stability in the sense of providing services has improved in Ethiopia as well.

Conflict or cooperation?

Interestingly, this new situation of an upstream challenge has been met by both increasing cooperation as well as an increasing prevalence of unilateral and potentially conflictive acts that support claims to water by attempts to create precedents for future actions. Examples include the land reclamation projects in Egypt and the Tana Beles and Tekezze dams in Ethiopia. Even in Sudan the Merowe dam is being built with Chinese support and without consulting Egypt (Cascão, 2009).

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[6] Government effectiveness is defined as "Capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (Kaufmann, Kraay & Mastruzzi, 2008).

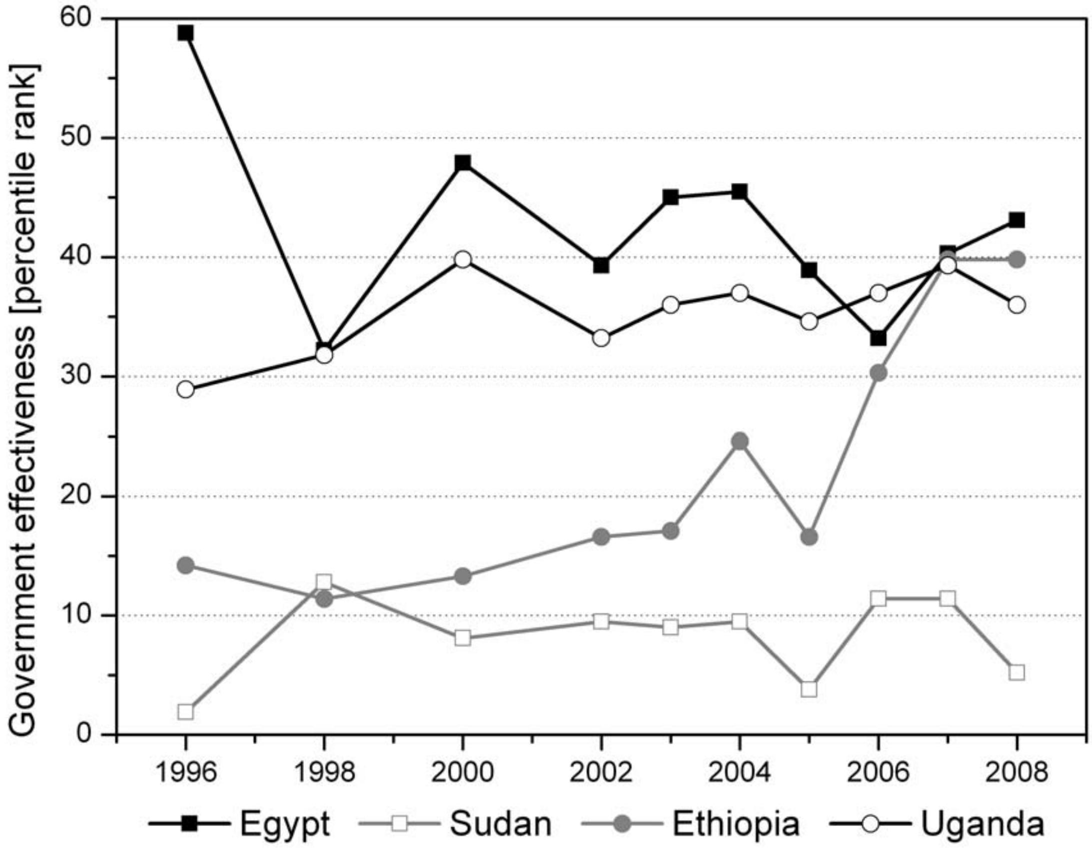

Figure 6: Government effectiveness measured as percentile rank (Data source: Worldwide Governance Indicators 2010).

The cooperative approach is two-fold as can be seen from recent initiatives (an overview of previous cases is given in Tesfaye (2008)). The Nile Basin Initiative (NBI), launched in 1999 and including all Nile Basin countries except Eritrea, focuses on specific projects and is an example of a rather technical cooperation, sharing benefits in order to build trust. At the same time high-level negotiations with the goal of a comprehensive basin-wide agreement (the so-called D3-project) are conducted.

The NBI was initially seen as an impressive example of transboundary water cooperation (Nicol et al, 2001) and opened the door for substantial western support and financial assistance which strengthened the cooperation. However, cooperation and negotiations have not been successful in overcoming the deep mistrust, especially between Ethiopia and Egypt. While Egypt feels continuously threatened by water projects implemented upstream[7], Ethiopia still views Egypt as unwilling to renegotiate water allocations to achieve a more equitable agreement. Egypt's position is increasingly endangering the cooperative process, as can be seen in the recent developments regarding the Cooperative Framework Agreement (CFA).

A draft CFA was negotiated in 2007 (NBI, 2007), but was not signed for three years due to disagreements over its status (as supplement to or replacement of the 1929 and 1959 treaties). In a unilateral move the upstream states finally opened the CFA for signature on May 14th 2010 for one year without the agreement of Egypt and

[7] An example is the reaction to the recent inauguration of the Tana Beles dam in Ethiopia in the Egyptian newspaper Al-Shorouq – an article titled "Nile source countries begin escalations against Egypt and Sudan." (Zohny, 2010).

Sudan[8]. The first signatories were Ethiopia, Uganda, Rwanda and Tanzania. Kenya followed on May 19th (Al-Masry Al-Youm, 2010). It was accompanied by strong reactions on both sides. Kenya's Minister for Water Charity Ngilu stated: "That treaty (1929) is obsolete. Nothing stops us to use the water as we wish. It is now up to Egypt to come on board" (Al-Masry Al-Youm, 2010). Egypt condemned the one-sided move. The Egyptian State Minister for Legal Affairs Mufid Shehab stated: "We do not want to view it as a destructive act, but we view it as a mistaken action and we should stop it" (Ethiopian News, 2010a). Egypt pushed for the cancellation of external funding to the signatories of the agreement[9] (Mayton, 2010), but in turn also offered more of its own aid to the upstream countries (Hamduillah & El-Badri, 2010).

Clearly these recent developments underline the shift to a now openly contested hegemony in the last 20 years. In addition to the rising upstream economic and bargaining power as well as exploitation potential discussed above, the signing of the CFA also shows increased ideational power – together the upstream states attempt to set the agenda. At this point it is too early to assess the impacts these events will have on the relations within the Nile Basin. Objectively, cooperation still holds the strong possibility of a win-win scenario for all parties. For this, the comparative advantages of the countries should be used (Mason, 2004; Whittington, 2004; Wichelns et al., 2003): HEP in Ethiopia[10], agriculture in Sudan, financial capabilities of Egypt, reduced evaporation losses by storing water upstream in Ethiopia rather than downstream in Sudan and Lake Nasser, increased trade in electricity, food and goods. However, if hostile rhetoric prevails, this outcome seems unlikely and a continuation of a challenged status quo in a cold conflict is probable.

The occurrence of conflict and cooperation concerning water resources in the Nile Basin in the past decades can be well categorized using the Transboundary Water Interaction Nexus matrix (TWINS) proposed by Zeitoun and Mirumachi (2008). While the main upstream vs. downstream conflict can be considered to be securitized, cooperation has evolved from quasi non-existent to rather technical to an unclear state at the moment, and a new chapter of relations within the Nile Basin has been opened recently with the signature of the CFA.

Climate change in the Nile river basin

The political developments in the Nile River basin in the recent past have already increased the complexity of the problem of water allocation among the riparians. Additional factors that come into play include variations in climatic conditions that can considerably affect the availability of water within the river system. While overall warming of the region appears likely, scenarios of future climate development in the Nile River basin do not agree with respect to trends in precipitation. This poses a challenge to the management of the limited water resources in this region.

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[8] While the text of the agreement is not publically available, and therefore cannot be discussed in detail here, the most important points are that no party has any veto power, developments regarding Nile waters must be undertaken cooperatively following the principle of equitable use, and the upstream countries get a higher water allocation (NBI, 2010).

[9] After initial support for Egypt, the World Bank apparently changed its stance, saying it would support the CFA if at least 6 riparian states would sign it. That would increase Egypt's predicament significantly (Leila, 2010).

[10] Ethiopia is already trying to "turn itself into a regional energy giant" and has signed electricity export contracts with Sudan, Kenya and Djibouti (Châtelot, 2010).

Observed trends

Previous assessments on the impact of climate change on the Nile river basin have been inconclusive. For the whole continent of Africa, since about 1960 a rise in mean annual temperature of about 0.5° C/century is observed (Hulme et al, 2001), while in Ethiopia and Uganda there is an increase of up to 1.3° C since 1960, with an increasing frequency of hot days and decreasing frequency of cold days (McSweeney et al, 2010). Precipitation trends are harder to observe due to an inherent high inter-annual and inter-decadal variability, and a high sensitivity of both the Ethiopian Highlands and the equatorial lakes region to even small climate variations (Elshamy, Sayed & Badawy, 2009)[11]. No statistically significant trend can be seen for the precipitation changes in Ethiopia from 1960-2000 (McSweeney et al, 2010, Ethiopia profile), though there are some indications that variability is increasing (FEWS NET, 2003). Overall, there seems to be a statistically significant decrease in mean annual precipitation in Uganda (McSweeney et al, 2010, Uganda profile). Reliable data on the flow of the Nile are difficult to find, especially for recent years. However, it is unlikely that among the natural variability any distinct trend would already be apparent that could be attributed to climate change, since changes in overall rainfall are so far minimal.

Future predictions

Future projections for the climate[12] depend on the particular emission scenario and the General Circulation Model (GCM) employed, and regional predictions tend to span a range of possible scenarios. For the Nile region the models generally agree on a further warming in a range of 1 to 5°C by the 2090s, with higher increases in the north of the basin (Egypt and northern Sudan) than in the south (Elshamy, Sayed & Badawy, 2009; Kim & Kaluarachchi, 2009).

Predictions on precipitation are less consistent, due to the high sensitivity and large disagreements in the prediction of phenomena like ENSO (Christensen et al, 2007). The most recent studies on the Blue Nile catchment region report conflictive results. For the 2090s, rainfall reductions are predicted in 10 out of 17 GCM models by Elshamy and others (2009), with a spread of -15% to +14% and basically no change for the ensemble mean. Kim and Kaluarachchi (2009) on the other hand find reductions for the 2050s in only 2 out of 6 GCMs, with a spread of -11% to +44%[13].

The resulting change in river flow has to take into account increasing evaporation due to increasing temperatures, which can reduce runoff even with higher precipitation. At the same time, more rain can lead to more cloud cover, higher humidity and lower temperatures reducing evaporation and increasing soil moisture, therefore potentially increasing runoff (Conway & Hulme, 1993; Elshamy, Seierstadt & Sorteberg, 2009).. Runoff is therefore even harder to predict. For the upper Blue Nile the ensemble means vary between +4% and -15% (Elshamy, Seierstadt & Sorteberg, 2009; Kim & Kaluarachchi, 2009) with spreads between -60% and +80%.

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[11] As an example, Blue Nile flows ranged from 20.6 km^3 in 1913 to 79 km^3 in 1909 (with a mean annual flow of 45.9 km^3 1961-1990). They are strongly influenced by the El Niño Southern Oscillation (ENSO) and Sahelian precipitation (Conway, 2005).

[12] A discussion of the methods to model climate change and their reliability is beyond the scope of this thesis. An overview can be found in Solomon (2007), a review of modeling of climate change and river outflows is provided in Xu (1999).

[13] Differences can be due to different emission scenarios of the Intergovernmental Panel on Climate Change used: Elshamy and others (2009) use A1B, Kim and Kaluarachchi (2009) use A2.

A prediction of the flow at Aswan has to take into account changes in the flow of both the Blue and the White Nile and vary wildly in the literature (Elshamy and others (2009): -62% to +43% with ensemble mean of +1%, Conway (2005): dry and wet case of -9% to +15% for 2025, Strzepek and others (2001) -90% to +18% in the 2090s).

Depending on climate change and variability[14], the region could experience a severe loss in agricultural productivity through water scarcity and land degradation (Agrawala et al, 2004). Even without the continuing mounting demographic pressure, this may intensify competition over the remaining arable farm land. Egypt and especially Cairo are particularly vulnerable to various impacts of climate change. The capital's infrastructure is already under pressure due to the Cairo's rapid growth. Egypt is the only country in the Nile Basin threatened by sea level rise, but that threat is substantial since the Nile delta is the country's most fertile, most populated, and most productive region. The extent of the rise is unclear at this point and no region-specific predictions can be found. By 2100, a rise between 0.28 and 0.43 m is expected, depending on the emission scenario (Nicholls et al, 2007). However, sea level rise due to thermal expansion is expected to continue for a very long time, even if mitigation measures were taken now. Therefore, the long term effects remain unclear.

Potential climate impacts on the occurrence of conflict and cooperation

Due to the uncertainty in the predictions for climate change in the Nile region, three basic scenarios should be included in a discussion of potential impacts of climate change on the occurrence of conflict and cooperation: reduced river flow, increased river flow, and unchanged river flow but increased variability.

When discussing the impacts on water supply, it has to be noted that the development of water demand may not be disregarded in this context, and it is likely to increase strongly. For a better overview, the possible scenarios and their associated impacts are summarized in Table I. The highest risk for intensified or even armed conflict occurs in the case of reduced river flow, particularly if the downstream states keep their position of insisting on maintaining the current status quo of water allocations based on the 1929 and 1959 agreements. In the case of increased flow, the pressure of increasing demand might be somewhat alleviated and the risk of increased conflict is lowered, since more water is there to be distributed. However, increases that are large enough to meet the expected increase in demand are unlikely to occur. In the situation of increased variability, the conflict potential is likely to stay the same, unless maybe in periods of extreme drought. In all three cases, a strong increase in the incentive for cooperation can be expected in order to achieve a win-win situation.

Climate change will also have an impact on the viability of both technical measures like dams and irrigation systems and treaties on water allocation (Tab. I). Technical measures built in certain areas may become unviable due to increased droughts, rendering irrigation unfeasible, or due to increased rainfall, overwhelming dam structures. In both cases, cooperation could help to achieve efficient use in the entire

[14] In this respect the possibility of a "greening of the Sahara" has been explored in the literature, due to interactions between vegetation cover and the atmosphere, which are particularly important in this 'hot spot' region. This was the case until about 6000 years ago and might happen again, with strong impacts also for the Nile region (Claussen, Brovkin & Ganopolski, 2002).

basin. ”Climate stability” needs to be ensured for all structures that already presently exist.

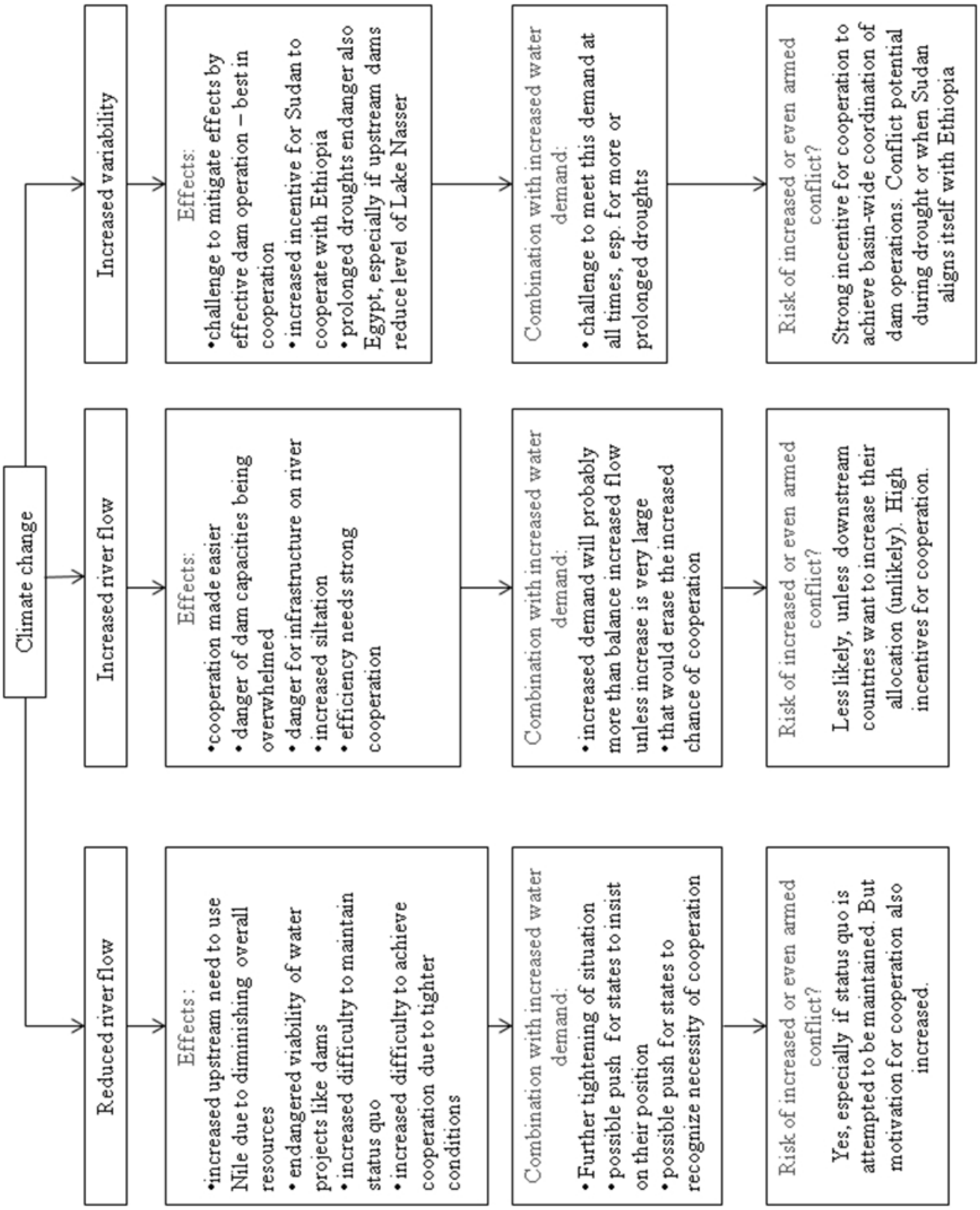

Table I: An overview of the effects of climate change on water supply and the link to the occurrence of conflict or cooperation, taking into account the likely increase in water demand due to climate change, population growth and development.

Treaties can become unstable if the water availability changes significantly. This is especially true for fixed allocation regimes (Ansink & Ruijs, 2008). In contrast, a “climate proof” agreement contains flexible allocation strategies and water quality criteria, provisions for extreme events, amendment and review procedures, as well as joint management institutions (Cooley et al, 2009). In this respect, the 1959 agreement between Egypt and Sudan was rather positive. Since the text of the new CFA is not yet publicly available, it cannot be tested here. The NBI can be regarded as a positive factor to prepare the basin for climate change. While so far climate change has not been a main focus of its work, the role of the NBI as a forum to share information, its research to understand the Nile system and especially its focus on development through sharing of benefits has created capacities that are useful in the context of climate change mitigation and adaptation as well. Currently a concrete project is being developed to address climate change impacts and adaptation within the NBI (NBI, 2008).

Finally, it is possible that climate change *directly* contributes to conflict or cooperation. First, it might be a facilitator of cooperation through disasters like floods and droughts, which can lead to a breakthrough in negotiations (Huisman, de Jong & Wieriks, 2000). However, such disasters already happen on a frequent basis in the Nile Basin without any significant impact on interstate relations. A higher frequency or strength of floods and droughts may overwhelm Egypt’s adaptive capacity by either overflowing or strongly reducing the water level in Lake Nasser, pushing it to more cooperation. At this point, however, this option seems unlikely.

Second, conflict could be caused through unilateral adaptation measures to climate change, which might have a direct impact on the possibility for adaptation in other countries (Goulden, Conway & Persechino, 2009). This is what currently already happens in the Nile River basin. Unilateral water development projects are implemented, even without climate change being invoked as a motivation. Again, as climate change intensifies, the impacts of such projects on the other countries could become more intense and thus increase the motivation for conflict. However, this development is also rather unlikely.

Therefore, climate change can hardly be considered as a direct cause for either conflict or cooperation in the Nile River basin at this point, in contrast to its potential as a threat multiplier. A process that is quite possible is the securitization of climate change in the Nile River basin. This includes a stronger instrumentalization of the vulnerability to climate change to justify actions and strengthen ideational power.

Model framework for the assessment of conflict potentials and cooperation

In order to be able to assess the possible consequences of changing environmental conditions on societal stability conflict in the Nile River basin, it is necessary to understand how climate change could influence resource availability, economic wealth, and the probability of conflicts arising. The interactions and causal relationships between the various driving factors influencing societal stability in the Nile River basin are shown in Figure 7. In this diagram, a dotted arrow indicates a positive impact, i.e. an increase of one factor causes an increase in the factor that is affected. A dashed arrow represents a negative impact, which implies that an increase in a particular variable leads to a decline in the variable that is affected. A solid arrow represents a feedback that is ambivalent or neutral. No arrow implies that no relevant impact is considered.

Changes in environmental conditions, which are shown on the left, influence water and land availability. These quantities in turn affect economic production. As human welfare and consequently societal stability depend on wealth, a deterioration of the economy can has negative implications on society as well. Since the water availability and therefore the conditions for agricultural production are affected by the water use further upstream, two main geographic regions (upstream and downstream) are distinguished. Also, there is a differentiation between the populations of rural and urban areas along the Nile River, because their economic activities differ substantially and the effects of climate change vary accordingly. Any large scale change in the structure of society, which may be caused by migration or population growth, triggers feedbacks that affect the economic output and subsequently the distribution of the remaining land and water resources.

Conflicts between the various actors can arise on different levels. First of all, there can be tensions between geographic regions. Increased use of resources in the upstream region diminishes the conditions for successful agricultural production downstream. Also, tensions may build due to the distinctly different structure of the populations in the rural and urban regions. These may increase in intensity if migration between these regions or particularly large population growth leads to larger competition over the limited resources available. Such conflicts are by no means limited to tensions between regions but could also manifest themselves in internal conflicts within a particular part of society.
Against the background of the impact graph of Figure 7 and based on a model framework for multi-agent conflict in environment and security (Scheffran & Hannon, 2007), we will focus on the interactions regarding water use and availability in the Nile River basin. For the four major riparian countries (Egypt, Sudan, Ethiopia, Uganda), we will discuss the options of each country for investing into water use and supply, either within the own national borders or in a neighbor country. Additionally, countries can use their investments to threaten each other to prevent or enforce certain actions by the other country. A schematic representation of the interactions of the countries in the model is shown in Figure 8.

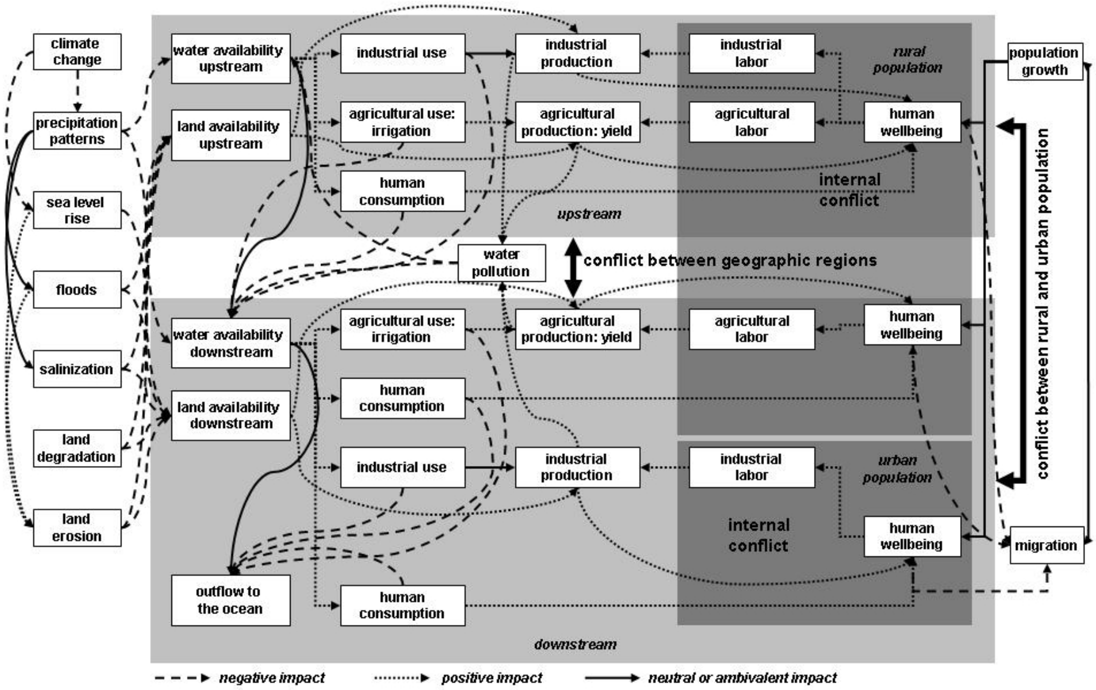

Figure 7: Schematic overview of the water conflict in the Nile River basin.

The change in water use and supply not only depends on the total investments made, but also on the unit costs and the fractions (priorities) of investments allocated to each action path. Each country is assumed to invest in at least one of the following action paths:

1. National water consumption without exceeding actual water supply

2. Increase national water supply.

3. Collaborate on water supply in an upstream country to benefit from increased external supply.

4. Threaten or pressure an upstream country not to reduce transboundary water supply by increased water consumption, or resist to threats by a downstream country.

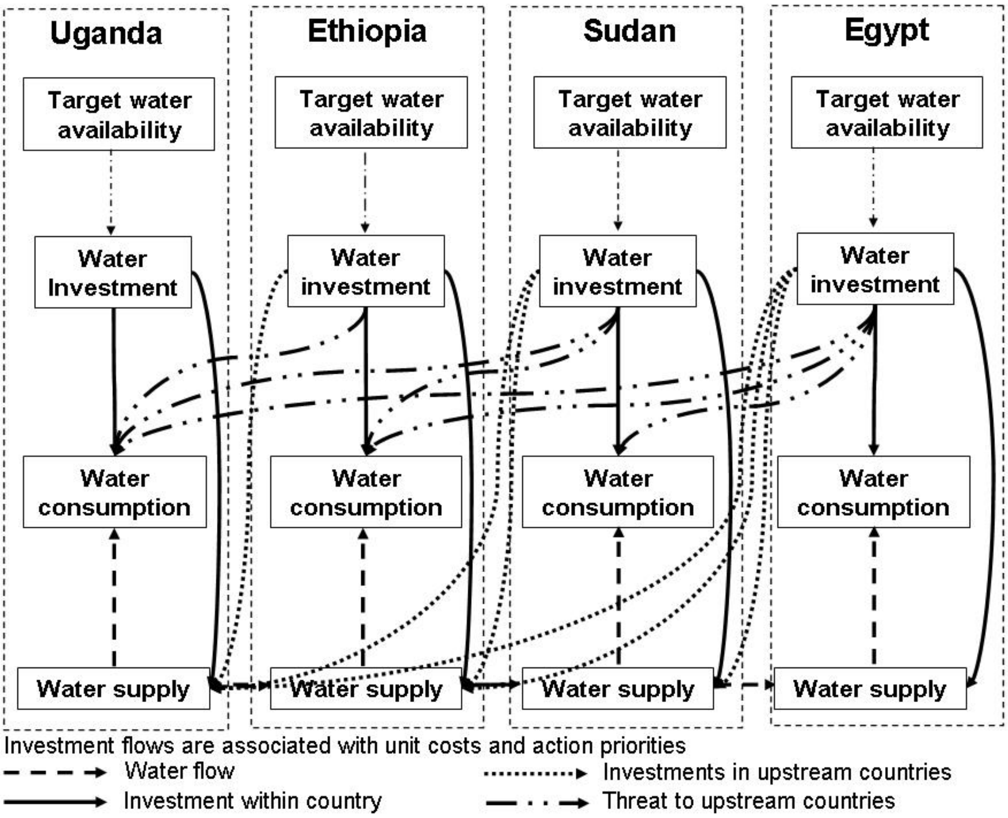

Figure 8: Interactions between the countries in the simulation model.

While the first two are unilateral measures, the third requires cooperation and the last is driving conflict between countries. Total change in water availability is the result of water-related investments of all countries and their associated impacts that also determine how the countries interact. We assume that the countries pursue certain future target paths for their water availability. These result in the target investments that each country requires to achieve its national water goals. They are affected by the investments of all other countries, and the unit costs and priorities of each action path. This interaction is represented by an adaptive dynamic system of difference equations with a temporal resolution of one year. It describes the dynamic interaction of the riparian countries that adjust their investment levels and control the dynamics by the speed of their response and by their priorities. By allocating the investment shares to the alternative action paths, the countries can influence the direction of their response.

Results of model simulations

In the simulation runs, each country starts with a typical initial Nile water consumption and supply. Then each country defines a target path for the change in water availability for a future period (in this case 20 years). This target path is based on population projections to satisfy the water needs of that population (assuming constant water demands per capita) and on the development of per capita water consumption.

It is assumed that each country is willing to apply a certain maximum investment into water availability, which is a given percentage of GDP that is not to be exceeded. Investments into water resources are initialized on the basis of actual water consumption in each country. They then adjust investment to the self-defined water demands within the investment limits, as described above.

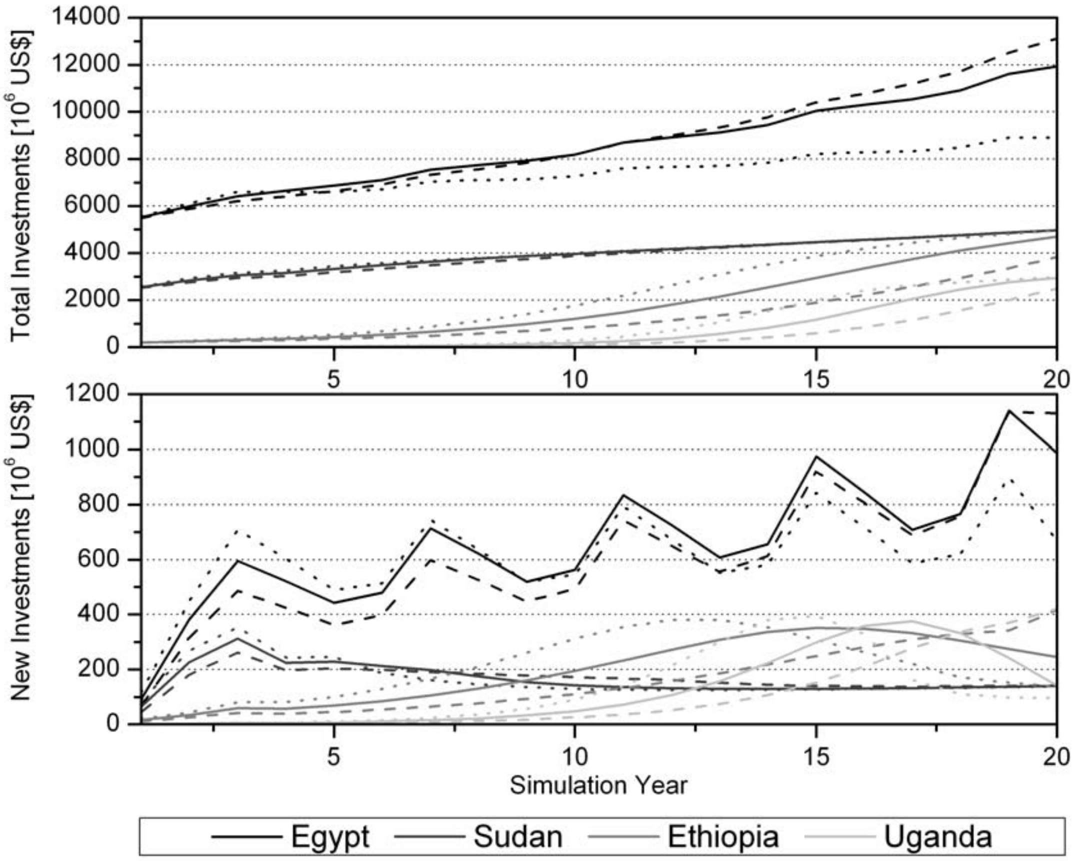

Figure 9a-b: Development of the total investments into water resources (top) and investments into the acquisition of additional water resources (bottom). The dashed lines denote the case of a climate change induced overall increase of water resources of 20% by the end of the simulation period, the dotted line a decrease of 20%. The solid lines denote a reference scenario with no climate change.

The water unit costs for the different action paths are selected to represent a situation, in which the unit costs for investing into increased water supply are considerably higher than the unit cost for water consumption, as long as the latter remains below the water supply. Domestic unit cost in Egypt is higher than in upstream countries, making it beneficial to also invest in upstream countries. Putting

pressure on an upstream country has a low unit cost if the neighboring country gives in to this pressure, but has the highest unit costs if this country resists, either by counter-pressure or by taking other non-cooperative action (including a possible military response).
We analyze two scenarios of climate change, reflecting the large projected climate variability. In the first case, climate change reduces water availability in the Nile Basin by 20% by the end of the 20-year simulation period, in the second case there is an increase by 20% over the same time horizon.

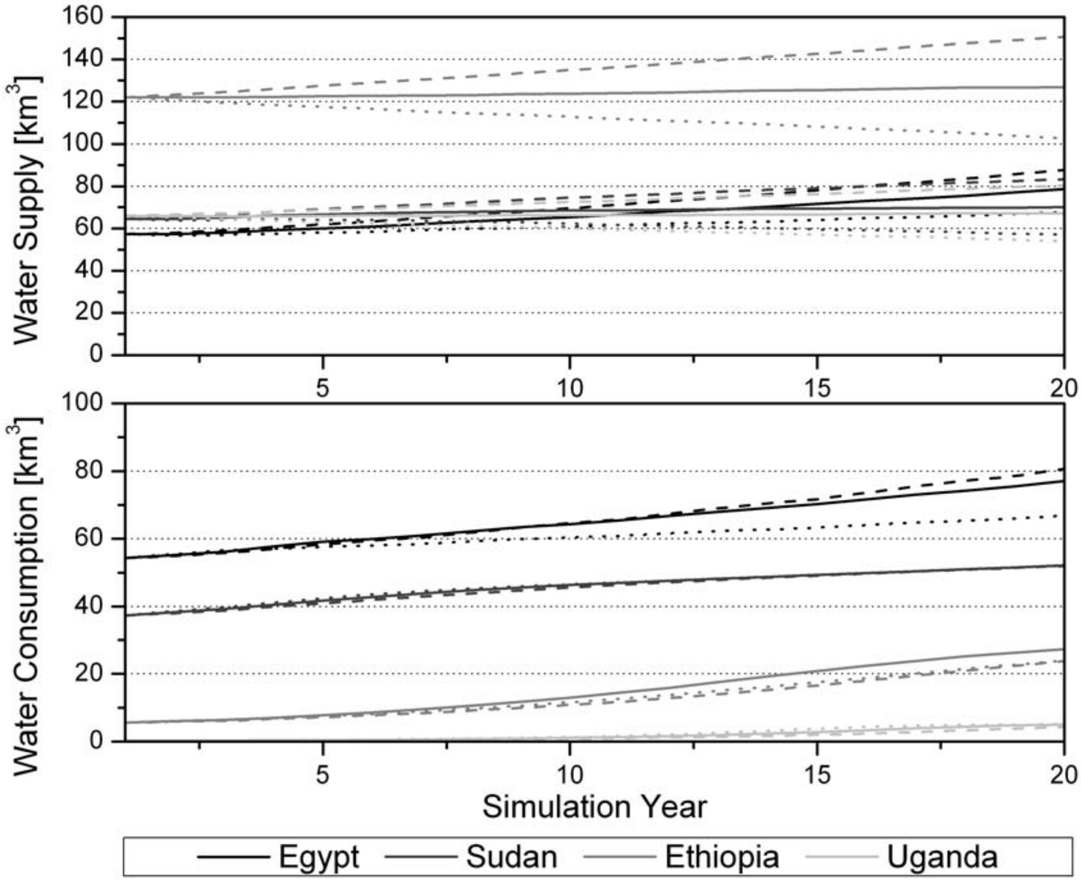

Figure 10a-b: Development of the water supply (top) and water consumption (bottom) in each country. The dashed lines denote the case of a climate change induced overall increase of water resources of 20% by the end of the simulation period, the dotted line a decrease of 20%. The solid lines denote a reference scenario with no climate change.

Investment into obtaining additional water resources to satisfy the growing water demand is initially generally highest when the water becomes scarcer, i.e. if there is a negative climate impact (Fig. 9). Countries have to invest more money as there is less water that is naturally available to them. The particularly strong increase in total investments (that also include the costs for the actual consumption of the water) in Egypt in the scenario with a growing overall water availability has to do with the fact that the intended expansion of water availability in this country leads to a hike in consumption costs within the increased supply limits.

Furthermore, the oscillations in the investments of Egypt into new water resources can be attributed to the fact that the country experiences switches between periods in which their strategy of threatening upstream countries is resisted, and those in which the pressure is accepted by the other country (Fig. 9). Investment costs are much higher in phases of resistance, which diminish the incentive to threaten and increase incentives to cooperate. This leads to a cyclic switch between phases of conflict and cooperation, as given by the boundary case shown in Fig. 9. If the difference in costs between resistance and non-resistance were larger than in the case shown, the countries would refrain from threatening their neighbors as the strategy becomes too costly in the long run.

The development of the water supply in the countries considered in the model coincides with the climate scenarios (Fig. 10). Without any climate change influence, there is only a slight expansion of water supplies as investments are made into new sources. However, this strategy is quite expensive. The climate change influence dwarves these efforts, as the supplies grow considerably if there is more water available naturally and shrinks much more than can be offset by investments if water becomes scarcer as a consequence of climate change. In contrast, the consumption in the upstream countries Ethiopia and Uganda increases in all scenarios, with the increase occurring earlier if there is a trend towards overall lower water availability. Due to the water consumption goals that are considerably higher than the initial consumption in these countries, fair amounts need to be invested. These investments occur earlier and to a larger extent if a decline in water availability can be expected. In a country like Egypt, in which the water consumption is close to the supply level throughout the simulation period, the negative development of overall water availability has an immediate effect on consumption despite all investment efforts to offset the effect of changing climate conditions.

Whether the strategies that are predominantly chosen are cooperative or conflictive depends on the relative costs involved in choosing the respective strategies. In our example shown only Egypt has a relevant incentive to impose pressure on its neighbor countries while the other countries usually fare best if they rely on investments in domestic infrastructure to improve their own consumption and supply levels.

Discussion and conclusions

The potential impacts of climate change pose a number of potential risks to international security, such as a rise in the number of weak states, risks for economic development and international conflicts over resources. Based on an assessment of the water-related conflict between countries in the Nile river basin with their asymmetric capabilities and adaptive capacities, this study discusses different pathways in which climate change could affect the water availability and conflict constellation in this region. An analysis of recent developments indicates that the hydro-hegemony status of Egypt is increasingly challenged by upstream states, which need water and hydropower for their own development and question previous legal water arrangements that favor Egypt. Instead, they promote a new institutional setting that provides a new balance between upstream and downstream states that Egypt hesitates to accept.

To understand future prospects for conflict or cooperation, a multi-agent dynamic model is applied. In this model, the countries invest into water supply and consumption to reach water development goals, depending on the unit costs of the action paths and a range of water availability due to climate change. The analysis suggests that the countries compete for the Nile water by increased investments, with Egypt temporarily putting pressure on upstream countries, but that cooperation provides a strategy to achieve water goals at reduced cost.

To address these challenges and to find a possible institutional framework for cooperative water management, a security architecture in the Northern African and Mediterranean region can play an important role. A strong cooperation between Europe and the North African countries on water and food security, energy and climate security can be beneficial for the entire region, increase adaptive capacity, substantially contribute to emission reduction especially in the power sectors, and create the preconditions for long term stability. Based on the Euro-Mediterranean Partnership, a Mediterranean and Human Security Initiative (MED-SEC initiative) would allow a balanced economic co-development across the Mediterranean, especially in the agricultural and energy sectors (Brauch, 2010).

A promising opportunity for strengthened North-South cooperation could be the vision of linking Europe to North Africa with electric power lines which is offered as an opportunity to combat climate change, and to meet its emission reduction and renewable energy obligations. For North African countries it is important to develop opportunities of meeting the increasing local energy and water demand, to attract substantial foreign investments, generate export benefits and open the way to technology sharing, employment opportunities and economic desalination.

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