On foes and flows: Water conflict and cooperation in the Nile River Basin in times of climate change

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Abstract

The Nile River Basin can be considered a climate security hot spot, as it is expected that this region will be severely affected by climate change. Rising temperatures and changing precipitation patterns exacerbate already existing problems of desertification, water scarcity, and food production, posing a challenge for the stability of the entire region. One of the most important issues for societal stability is the allocation of water resources among the riparian countries. Based on data of key countries in the Nile River Basin regarding various economic, environmental, developmental, and political dimensions, an analysis of possible regional security implications and conflicts is conducted that may arise if the influence of climate change alters the current status quo. 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 consider shifting towards strategies that are based on threats rather than on cooperation.

1 Introduction

The Nile River Basin (Fig. 1) is a region with a long cultural history that is tightly connected to the river itself, which has been serving as a lifeline for the entire region. In the past millennia, the peoples living in the catchment basin of the Nile River have adapted to life with and from the river. Because of the lack of alternatives, a sufficient water supply from the Nile River is critical for many of the countries in this region, with particularly large portions of the population relying on Nile waters in Egypt, Sudan, Ethiopia, and Uganda. These are also the focus countries of this paper[1]. In more recent history, the flow behavior of the stream has been significantly altered by the construction of large dams. Furthermore, the water allocation between the riparian states is being governed by agreements that historically favor the downstream states Egypt and Sudan. Today the Nile Basin countries are facing large challenges regarding demographic and socio-economic development, with a large but decreasing discrepancy between the level of development of Egypt and the other riparian states. The population growth and push for economic development is steadily increasing the

[1] The other riparian states are South Sudan, Djibouti, Kenya, Tanzania, Rwanda, Burundi, and the Democratic Republic of Congo. Since South Sudan only gained independence from Sudan in 2011, there are no data available on this country, which is therefore generally not considered separately from Sudan in this paper.

pressure on the Nile River as a water resource, while the attempts to develop a basin-wide agreement on the Nile water use have not been successful so far and a situation of low-level conflict remains[2]. Under these circumstances climate change can act as an additional pressure factor and risk multiplier, magnifying the effects of other current pressures and challenges that could possibly trigger conflict and social destabilization.

In recent years, an increasing attention has been paid by researchers to the potential security risks and conflicts associated with climate change[3]. Simple assertions of "climate wars" did not find empirical grounding and previous research on the link between climate change and violent conflict has so far been inconclusive. It rather points towards possible increases in non-state small-scale violence than in inter-state wars, with climate change acting in concert with other conflict factors rather than being a sole driver[4]. However, with increasing scientific interest in the subject it becomes also increasingly clear that the interconnections between environmental conditions, resource scarcity, human wellbeing, and possible societal instability are very complex and difficult to assess quantitatively. Therefore, in this paper the question of the impact of climate change on inter-state conflict or cooperation over the Nile waters is picked up and analyzed in a complex framework, taking into account

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[2] Ana Elisa Cascão, "Changing Power Relations in the Nile River Basin: Unilateralism Vs. Cooperation?," *Water Alternatives* 2, no. 2 (2009).

[3] Alexander Carius, Dennis Tänzler, and Achim Maas, *Climate Change and Security - Challenges for German Development Cooperation* (Eschborn: Gesellschaft für technische Zusammenarbeit [GTZ], 2008); Hans Günter Brauch, "Securitzing Global Environmental Change," in *Facing Global Environmental Change: Environmental, Human, Energy, Food, Health and Water Security Concepts*, ed. Hans Günter Brauch, et al., *Hexagon Series on Human and Environmental Security and Peace* (Berlin, Heidelberg, New York: Springer, 2009); Michael Brzoska, "The Securitization of Climate Change and the Power of Conceptions of Security," *Security and Peace* 27, no. 3 (2009); Halvard Buhaug, Nils Petter Gleditsch, and Ole Magnus Theisen, "Implications of Climate Change for Armed Conflict," in *Social Dimention of Climate Change*, ed. Robin Mearns and Amdrew Norton (Washington: World Bank, 2010); Jürgen Scheffran and Antonella Battaglini, "Climate and Conflicts: The Security Risks of Global Warming," *Regional Environmental Change* 11, no. Supplement 1 (2011).

[4] J. Barnett, "Security and Climate Change," *Global Environmental Change-Human and Policy Dimensions* 13, no. 1 (2003); Jon Barnett and W. Neil Adger, "Climate Change, Human Security and Violent Conflict," *Political Geography* 26(2007); Ragnhild Nordås and Nils Petter Gleditsch, "Climate Change and Conflict," *Political Geography* 26, no. 6 (2007); Nils Petter Gleditsch, "Special Issue on Climate Change and Conflict," *Journal of Peace Research* 49, no. 163 (2012); Jürgen Scheffran et al., eds., *Climate Change, Human Security and Violent Conflict: Challenges for Societal Stability* (Berlin: Springer, 2012).

the additional pressure factors acting in the Nile Basin states. The goal is to assess whether climate change is likely to have an effect on the current political and social situation in the Nile River Basin with respect to potential conflict or cooperation about water resources.

The key issue in this regard is the vulnerability of the Nile Basin states to climate change effects on the Nile River. The IPCC defines vulnerability as the "degree, to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. (...) Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity."[5]. If the Nile riparians are highly vulnerable to changing water availability under climate change, their positions regarding the allocation of Nile water may shift, unilateral actions could be taken and the potential for conflict could increase[6]. However, a decisive dimension of vulnerability is adaptive capacity, the capability to respond and prepare to resulting challenges. Therefore, another possible outcome is the joint increase of adaptive capacities through cooperation[7]. This paper analyzes the vulnerabilities and adaptive capacities of Nile riparians and explores possible pathways to both conflict and cooperation as a result of an additional pressure from climate change. The issue is addressed by looking at the causal chain from climate change to conflict (Fig. 2) in a systematic manner.

This analysis is timely since the implications of climate change have recently become a prominent issue on the agenda of the riparian countries. This issue was addressed in detail in the 3rd Nile Basin Development Forum, which took place in October 2011 in Kigali, Rwanda.

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[5] IPCC, *Climate Change 2007. Climate Change Impacts, Adaptation and Vulnerability. Contribution of Working Group Ii to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: Cambridge University Press, 2007).

[6] 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.

[7] A difficulty in assessing this hypothesis lies in the changing nature of adaptive capacities, which are not fixed but can grow with the challenge.

The meeting focused on “Climate change and its implications for sustainable development and cooperation in the Nile Basin” and aimed at the establishment of sound cooperation in order to successfully adapt to changing environmental conditions. The Forum formulated 12 recommendations concerning adaptation governance, adaptation finance and food and energy security that the Nile Basin Initiative should use as a basis to design and implement concrete adaptation measures against climate change in the Nile River Basin[8].

The framework for the assessment is presented in section 2. Subsequently, the development of conflict and cooperation over water from the Nile River is looked at in section 3, providing the background information for the assessment. Sections 4 and 5 examine the key factors of the vulnerabilities of the Nile River riparians to changing climatic conditions as well as their adaptive capacities. The findings are brought together in section 6 to address the possible relation of climate change to future cooperation or conflict over Nile waters. Section 7 concludes.

2 Framework for the assessment of conflict potentials and cooperation

There is no simple relationship between climate change, water resources, and potential conflict in the Nile River Basin. Changes in environmental conditions can influence resource availability, economic wealth, and – depending on the institutional structures – the probability of conflict[9]. The key dimensions and factors influencing societal stability in the Nile River Basin are shown in Figure 2. Changes in environmental conditions are an external forcing that first influences key resources such as water and land availability. These quantities in turn affect economic production and the consumption of resources, which affects human well-being and, because of the transboundary setting of the river basin, relations between riparian

[8] Nile Basin Initiative, "Kigali Recommendations" (paper presented at the 3rd Nile Basin Development Forum, Kigali, Rwanda, 28.10.2011 2011).

[9] Jürgen Scheffran, Peter Michael Link, and Janpeter Schilling, "Theories and Models of the Climate-Security Interaction: Framework and Application to a Climate Hot Spot in North Africa " in *Climate Change, Human Security and Violent Conflict*, ed. Jürgen Scheffran, et al., *Hexagon Series on Human and Environment Security and Peace* (Berlin: Springer, 2012).

states. These can be cooperative or conflictive. Whether possible pressures on societal stability lead to increased conflict depends critically on the adaptive capacity or the vulnerability of a society. As long as a society is able to successfully deal with the challenges imposed by changing environmental conditions, the likelihood of onset of additional conflict is limited. Therefore, the countries in the Nile River Basin should look to increase their joint adaptive capacity despite possible internal tensions due to conflicting resource demands.

The most obvious tension occurs between the different geographic regions – upstream and downstream – as distinguished in the scheme. The downstream countries Sudan and especially Egypt depend almost exclusively on the Nile as a water resource. However, the water availability in the downstream countries depends on the water use in the upstream countries. Increased use of water in the upstream region leaves less water available for consumption and agricultural production in the downstream region. There are other possibilities of conflict on sub-national level related to societal instability, for example between different users of limited water, like herders and farmers or rural and urban communities. However, a discussion of this is beyond the scope of this paper.

Finally, there are feedbacks and other pressure effects in the system, most importantly demographic change and development. These also affect land and water resources and economic output, and therefore are important in the final analysis of transboundary relations.

The region has a long history of water conflict and cooperation attempts, and an extensive body of literature analyzes this. The following section briefly reviews the positions of the decisive actors as well as the most important milestones shaping inter-state relations in the Nile Basin as a basis for the further analysis.

3 Actors in and milestones of conflict and cooperation over the Nile River

A main shaping element of the conflict history of the Nile River Basin is the historic asymmetry between downstream Egypt as the hydro-hegemon[10] of the basin on the one side and the upstream states on the other. Hydro-hegemony rests on the three pillars of riparian position, power (military, economic, bargaining, ideational, political), and exploitation potential. Despite its downstream position, Egypt has been by far the dominating country in the other two dimensions and has shaped the discourse and actions on water allocation in the Nile River Basin. This status of Egypt can be mainly traced back to the extensive external support Egypt enjoyed historically due to its particularly important strategic geographic position, most importantly from Great Britain in colonial times, from the Soviet Union, which supported the construction of the Aswan High Dam, and the USA[11]. It also is related to Egypt's high dependence on the Nile waters, with basically no other sources of renewable water[12]. Therefore, it has a long-standing interest to preserve in treaties what it views as 'historic rights' to the river.

The two most important treaties forming the base of today's water allocations and of the conflict date back to colonial times. The 1929 treaty between the colonial United Kingdom and Egypt granted 48 km^3 per year to Egypt and 4 km^3 per year to Sudan, institutionalizing the belief that Egypt and Sudan had 'natural and historic rights' to the Nile water"[13]. It was never recognized by Ethiopia and, after their independence, was also contested by the other former colonies in the Nile River Basin.

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[10] Mark Zeitoun and Jeroen Warner, "Hydro-Hegemony: A Framework for Analysis of Trans-Boundary Water Conflicts," *Water Policy* 8, no. 5 (2006); Cascão, "Changing Power Relations in the Nile River Basin: Unilateralism Vs. Cooperation?."

[11] John Anthony Allan, "Nile Basin Asymmetries: A Closed Fresh Water Resource, Soil Water Potential, the Political Economy and Nile Transboundary Hydropolitics," in *The Nile* (2009); Cascão, "Changing Power Relations in the Nile River Basin: Unilateralism Vs. Cooperation?."; Franziska Piontek, "The Impact of Climate Change on Conflict and Cooperation in the Nile Basin" (University of Hamburg, 2010).

[12] John Waterbury, *Hydropolitics of the Nile Valley*, Contemporary Issues in the Middle East (Syracuse, N.Y.: Syracuse University Press, 1979).

[13] Cascão, "Changing Power Relations in the Nile River Basin: Unilateralism Vs. Cooperation?," 245.

Due to the construction of the Aswan High Dam, an adjustment of the water allocations became necessary between Egypt and Sudan. The 1959 agreement entitled Sudan to 18.5 km^3 per year and Egypt to 55.5 km^3 per year. Taking into account the evaporation of 10 km^3 per year over Lake Nasser, this amounts to the full 100% of the Nile River flow of 84 km^3 per year. Thus, this treaty implicitly left no water to the upstream countries of the Nile River. Consequently, this agreement established a strong division among the different geographic regions of the Nile River Basin. On one side, there is an alliance between Egypt and Sudan who want to maintain this agreement. On the other side this treaty is opposed by the upstream states that criticize this bilateral agreement and want to replace it by an agreement that is based on equitable water shares[14]. The main positions of the two groups are summarized in Table 1. Any scheme attempting to strengthen cooperation on water issues in the Nile River Basin needs to overcome the asymmetry in Nile water dependency and water distribution since the dependency is highest in the downstream states.

Table 1: Positions of states regarding the Cooperative Framework Agreement. In this context, downstream states are Egypt and Sudan, upstream states are Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, and the Democratic Republic of Congo.

Downstream states	Upstream states
- Principle: No harm - Acquired rights and prior use - Retain existing agreements and allocations - Prior notification of projects regarding the Nile - Information exchange - Keep status quo	- Principle: Equitable utilization - New comprehensive agreement for the whole basin - New uses of water, new allocations - New investments without notification or downstream veto – ensure access to international funding - Change status quo

Despite the contrary positions and much conflictive rhetoric, many initiatives for cooperation have in fact been brought forward by the Nile countries. The most extensive efforts, which for the first time included all 10 riparians, started in 1999 with the goal to negotiate a new water agreement "to achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water

[14] Waterbury, *Hydropolitics of the Nile Valley*.

resources" (cf. www.nilebasin.org). It includes the Nile Basin Initiative (NBI), an institutional framework that has established multiple cooperative projects on the ground in the last decade. In parallel a negotiation process towards a new Cooperative Framework Agreement (CFA) (Tab. 1) was initiated.

In 2010 and 2011, several considerable upheavals have occurred in the Nile River Basin, which are still unfolding and whose implications for future intra-basin relations remain to be seen. The first was the unilateral opening of the signature process for the draft CFA by the upstream states in May 2010. A draft CFA was negotiated in 2007[15] but was not signed for three years due to disagreements over its status in relation to the former treaties (supplement or replacement). The first signatories of the draft CFA, known as Entebbe Treaty, were Ethiopia, Uganda, Rwanda and Tanzania, followed by Kenya[16]. With the signature of Burundi in February 2011 as the sixth country, the ratification of the agreement can now proceed even if Egypt and Sudan continue to oppose this move on the grounds of retaining their veto power on water developments in the Nile River Basin[17]. These events reflect the increasing ability and desire of the upstream states to challenge Egypt's status as hydro-hegemon and the overall status quo. This can be related to increasing economic development and stability as well as international support by a new actor, China, which improves the upstream exploitation potential[18].

Besides the developments directly related to water issues, there were considerable political changes in the region that can have a significant influence on the boundary conditions under which any future cooperation on water resources is set up. The revolution in

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[15] NBI, "The Nile Council of Ministers Responsible for Water Affairs (Nile-Com) Concluded Negotiations," (2007), http://www.nilebasin.org/index.php?option=com_content&task=view&id=48&Itemid=70.

[16] Al Masry Al Youm, "Kenya Signs Nile Basin Deal, Rules out Discussion with Mubarak."

[17] "Global Insider: Nile Basin Water Rights," *World Politics Review*(2011), http://www.worldpoliticsreview.com/trend-lines/8520/global-insider-nile-basin-water-rights.

[18] see Cascão, "Changing Power Relations in the Nile River Basin: Unilateralism Vs. Cooperation?."; Piontek, "The Impact of Climate Change on Conflict and Cooperation in the Nile Basin". for further discussions

Egypt and the toppling of President Mubarak in February 2011 opens the opportunity for a new Egyptian approach towards regional integration and cooperation over the Nile waters. The independence of South Sudan in July 2011 and therefore the emergence of a new riparian state harboring the Sudd Swamps, an ecosystem crucial for the flow of the White Nile due to its large evaporation rates, has the potential of influencing upstream-downstream relations by new coalition opportunities. While it is too early for a detailed analysis of the impact of these events, they will be important for the future of cooperation in the Nile River Basin.

After setting the stage regarding the historical and current political situation, the analysis in the next two sections will focus on the key factors determining the possible impact climate change may have on the occurrence of conflict or cooperation in the Nile River Basin. This is done by assessing the vulnerability of the region to climate change and the adaptive capacities of the riparians. Many dimensions of vulnerability and adaptive capacity are of course strongly interconnected with the historic power distribution in the Nile River Basin.

4 The Nile Basin countries' vulnerability to climate and climate change

The Nile River Basin is considered to be one of the climate hot spots, which means that this region is likely to be particularly affected by changes in environmental conditions due to anthropogenic climate change[19]. However, the following sections will show that, due to the diverse nature of the Nile River Basin, climate change will not affect all parts of this region equally. Furthermore, as will be discussed, the countries show differences in the degree to which they are able to deal with the challenges connected to climate change. Thus, the vulnerability to a changing climate varies quite substantially in the Nile Basin, augmenting differences already found between upstream and downstream states and therefore possibly altering their positions towards conflict and cooperation.

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[19] WBGU, *World in Transition - Climate Change as a Security Risk* (London: Earthscan, 2008).

According to the IPCC definition of vulnerability (see introduction) the three determining factors for vulnerability are exposure, sensitivity and adaptive capacity. Due to its importance and complexity, adaptive capacity is discussed separately in section 5. This section assesses exposure and climate sensitivity in light of the Nile water conflict.

4.1 Exposure

Exposure to climate effects and climate change is strong in all Nile countries. One dimension is current climate variability, which is very high throughout the basin. This includes highly variable Nile flows as well as frequent floods and droughts[20]. For a detailed discussion of the climate in the Nile River Basin see Sutcliffe & Parks[21].

The second dimension of exposure is the expected impact that climate change will have in the region, which is likely to be considerable depending on the sensitivity of the Nile River Basin to changes in environmental conditions. However, predictions are difficult at this point, which is partially due to the inherent variability, but also to difficulties in making accurate predictions on relatively small geographic scales[22]. In the following we provide a summary of the current state of knowledge on climate change impacts in the Nile River Basin.

4.1.1 Observed trends

So far, assessments on the impact of climate change on the Nile River Basin have been inconclusive. For the entire continent of Africa, since about 1960 a rise in mean annual

[20] D. Conway, "From Headwater Tributaries to International River: Observing and Adapting to Climate Variability and Change in the Nile Basin," *Global Environmental Change-Human and Policy Dimensions* 15, no. 2 (2005); Declan Conway et al., "Rainfall and Water Resources Variability in Sub-Saharan Africa During the Twentieth Century," *Journal of Hydrometeorology* 10(2009).

[21] J. V. Sutcliffe and Y. P. Parks, *The Hydrology of the Nile - Iahs Special Publication No. 5* (Wallingford/England: International Association of Hydrological Sciences, 1999).

[22] IPCC, *Climate Change 2007. Climate Change Impacts, Adaptation and Vulnerability. Contribution of Working Group Ii to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

temperature at a rate of about 0.5° C/century is observed[23], while in Ethiopia and Uganda an increase of up to 1.3° C has been observed between 1960 and 2006, with an increasing frequency of hot days and decreasing frequency of cold days[24].

Precipitation trends are harder to identify due to an inherently higher inter-annual and inter-decadal variability, and high climate sensitivity. No statistically significant trend can be observed for the precipitation changes in Ethiopia between 1960 and 2000[25]. However, there are some indications that variability is increasing[26]. Overall, there seems to be a statistically significant decrease in mean annual precipitation in Uganda[27]. Reliable data on the flow of the Nile are difficult to find, especially for recent years. Nonetheless, it is unlikely that any distinct trend would already be apparent among the natural variability that could be attributed to climate change since changes in overall rainfall amounts are minimal until present.

4.1.2 Future predictions

Future projections for the development of the climatic conditions in the Nile River Basin are critically dependent not only on the particular emission scenario applied but also on the General Circulation Model (GCM) employed. Consequently, 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°C to 5°C by the 2090s, with higher increases in the north of the basin (Egypt and northern Sudan) than in the south[28].

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[23] Mike Hulme et al., "African Climate Change: 1900-2100," *Climate Research* 17, no. 2 (2001).

[24] C. McSweeney, M. New, and G. Lizcano, "Uganda," in *UNDP Climate Change Country Profiles* (United Nations Development Programme, 2010); "Ethiopia," in *UNDP Climate Change Country Profiles* (United Nations Development Programme, 2010).

[25] McSweeney, New, and Lizcano, "Ethiopia."

[26] Philip Steffen et al., "Rainfall in Ethiopia Is Becoming Increasingly Erratic," (Famine Early Warning Systems Network, 2003).

[27] McSweeney, New, and Lizcano, "Uganda."

[28] U. Kim and J. J. Kaluarachchi, "Climate Change Impacts on Water Resources in the Upper Blue Nile River Basin, Ethiopia," *Journal of the American Water Resources Association* 45 no. 6 (2009); M. E. Elshamy, M. A. A. Sayed, and B. Badawy, "Impacts of Climate Change on the Nile Flows at Dongola Using Statistical Downscaled Gcm Scenarios," *Nile Basin Water Engineering Scientific Magazine* 2 (2009).

Predictions on precipitation are less consistent. This is mainly because of the high sensitivity of precipitation in climate models and large disagreements in the prediction of phenomena like the El Niño Southern Oscillation[29]. 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[30], with a spread of -15% to +14% and basically no change for the ensemble mean. Kim and Kaluarachchi[31] on the other hand find reductions for the 2050s in only 2 out of 6 GCMs, with a spread of -11% to +44% .

The resulting change in river flow has to take into account increasing evaporation due to rising temperatures, which can reduce runoff even with growing precipitation. At the same time, more rain can lead to an expanded cloud cover, higher humidity and lower temperatures, causing reduced evaporation and increased soil moisture, therefore potentially increasing runoff[32]. Runoff is therefore even harder to predict. For the upper Blue Nile model results of runoff vary between +4% and -15% by the second half of the 21st century[33], with spreads between -60% and +80%. A prediction of the flow at Aswan has to take into account changes in the flow of both the Blue and the White Nile. Both values vary extensively in the literature. Thus, the prediction of downstream flows in the Nile River can just be an estimate of the correct order of magnitude. Elshamy and others[34] report downstream flow changes of -62% to

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[29] J.H. Christensen et al., "Regional Climate Projections," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon, et al. (2007); Conway et al., "Rainfall and Water Resources Variability in Sub-Saharan Africa During the Twentieth Century."

[30] M. E. Elshamy, I. A. Seierstadt, and A. Sorteberg, "Impacts of Climate Change on Blue Nile Flows Using Bias-Corrected Gcm Scenarios," *Hydrology and Earth System Sciences* 13 (2009).

[31] Kim and Kaluarachchi, "Climate Change Impacts on Water Resources in the Upper Blue Nile River Basin, Ethiopia."

[32] D. Conway and M. Hulme, "Recent Fluctuations in Precipitation and Runoff over the Nile Sub-Basins and Their Impact on Main Nile Discharge," *Climatic Change* 25, no. 2 (1993); Elshamy, Seierstadt, and Sorteberg, "Impacts of Climate Change on Blue Nile Flows Using Bias-Corrected Gcm Scenarios."

[33] Elshamy, Seierstadt, and Sorteberg, "Impacts of Climate Change on Blue Nile Flows Using Bias-Corrected Gcm Scenarios."; Kim and Kaluarachchi, "Climate Change Impacts on Water Resources in the Upper Blue Nile River Basin, Ethiopia."

[34] Elshamy, Seierstadt, and Sorteberg, "Impacts of Climate Change on Blue Nile Flows Using Bias-Corrected Gcm Scenarios."

+43% with ensemble mean of +1%, Conway[35] distinguishes a dry and a wet case of -9% to +15% for 2025, Strzepek and others[36] predict changes between -90% and +18% in the 2090s.

Egypt is the only country of the Nile Basin considered in this assessment that is threatened by sea level rise. Nonetheless, that threat is substantial since the Nile delta is the country's most fertile, most densely populated, and agriculturally most productive region. The extent of the rise in sea level is unclear at this point and no region-specific predictions can be found. By 2100, a sea level rise between 0.28 and 0.43 m is expected, depending on the emission scenario[37]. However, sea level rise due to thermal expansion is expected to continue for a very long time, even if successful mitigation measures were taken at present. Therefore, the long term effects remain unclear.

4.2 Sensitivity

In the context of climate sciences, sensitivity can be defined as "the degree to which a system is affected, either adversely or beneficially, by climate variability or change"[38]. This can be either a direct or an indirect effect. The Nile River Basin as a natural system is very sensitive to even small climate variations, particularly in the Ethiopian Highlands and the equatorial lakes region[39].

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[35] Conway, "From Headwater Tributaries to International River: Observing and Adapting to Climate Variability and Change in the Nile Basin."
[36] K. M. Strzepek et al., "Constructing "Not Implausible" Climate and Economic Scenarios for Egypt," *Integrated Assessment* 2 (2001).
[37] Robert J. Nicholls et al., "Coastal Systems and Low-Lying Areas," in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group Ii to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Martin L. Parry, et al. (Cambridge, UK: Cambridge University Press, 2007).
[38] IPCC, *Climate Change 2007. Climate Change Impacts, Adaptation and Vulnerability. Contribution of Working Group Ii to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.
[39] Sutcliffe and Parks, *The Hydrology of the Nile - Iahs Special Publication No. 5*; Conway, "From Headwater Tributaries to International River: Observing and Adapting to Climate Variability and Change in the Nile Basin."; Elshamy, Sayed, and Badawy, "Impacts of Climate Change on the Nile Flows at Dongola Using Statistical Downscaled Gcm Scenarios."

At the same time, the current socio-economic system of the Nile countries is highly climate sensitive as well. This can be deduced from devastating effects of natural disasters like floods and droughts in the past decades (Tab. 2).

Table 2: Natural disaster statistics for the period from 1970-2011[40].

	# of events	# of people affected [millions]	# of people killed [thousands]	# of people homeless [thousands]	Economic damage [million US$]	Most common type of event
Egypt	21	0.2	0.9	53.2	156	floods, storms, extreme temperatures
Ethiopia	87	65.1	414.0	195.6	108	floods, epidemics, droughts
Sudan	78	32.2	160.7	1453.5	551	epidemics, floods, droughts
Uganda	59	5.8	2.0	320.7	2.7	epidemics, floods, droughts

With respect to possible climate change effects in the future on the transboundary water resources of the Nile River Basin, the sensitivity of countries is high as well. The main factors in that regard are the high dependency of most riparian economies on the agricultural sector, including already high levels of irrigation in some areas and high dependency on rain-fed agriculture in others, the increasing use of the Nile for energy generation through hydro-electric power (HEP), which is an important development factor, and in general the location of settlements and infrastructure along the river.

Figure 3 shows the importance of the agricultural sector in the countries' economies for GDP and employment. For large parts of the rural populations – especially in the upstream countries – rainfed agriculture is the main basis of their livelihoods. Climate change is expected to have an important impact on agriculture by changing the crop yield, the water requirements, growing seasons and the occurrence of crop diseases[41]. Water availability for irrigation becomes even more crucial but at the same time also less reliable due to climate

[40] Centre for Research on the Epidemiology of Disasters CRED, "Em-Dat - the International Disaster Database - Natural Disasters Trends," http://www.emdat.be/natural-disasters-trends.

[41] S. Agrawala et al., "Development and Climate Change in Egypt: Focus on Coastal Resources and the Nile," (Paris, France: Organisation for Economic Co-operation and Development, 2004); Christoph Müller et al., "Climate Change Risks for African Agriculture," *Proceedings of the National Academy of Sciences* 108, no. 11 (2011); J. Gornall et al., "Implications of Climate Change for Agricultural Productivity in the Early Twenty-First Century," *Philosophical Transactions of the Royal Society B* 365(2010).

change. The detailed predictions vary substantially and highly depend on assumptions on the effect of CO_2 fertilization, specific local conditions and on the types of crops grown, but in general a reduction of crop yields and production is expected for Africa and the Nile countries. Food availability could drop by 21% in Sub-Saharan Africa[42], with the Ethiopian highlands as a possible exception. Cash crops, a crucial source of revenue in some of the countries of the Nile River Basin, will be affected by this development as well; one example is coffee in Uganda[43].

The water sector is sensitive to the increasing unpredictability with regard to precipitation and thus to the variability in the water levels and overall water availability. More erratic rainfall can already be observed in Sudan[44] and frequent changes of water levels in lakes and reservoirs are the consequence. Higher as well as lower levels of rainfall can be a problem. An example is the recent drop of Lake Victoria, causing problems with irrigation, fisheries (which are also adversely affected by higher lake temperatures) and HEP produced at Owen Falls Dam, which is Uganda's major source of electricity[45]. Consequently, HEP, which is general considered as a very important factor for socio-economic development in the region, is also highly sensitive to climate change. On the demand side, an increase in water use due to increasing temperatures is likely for all sectors, including a growing human demand, industrial demand (e.g. cooling), and agricultural demand (e.g. irrigation). This leads to an increasing "pressure on water resources already under pressure"[46]. Climate change is

[42] Gerald C. Nelson et al., *Climate Change - Impact on Agriculture and Costs of Adaptation* (Washington: International Food Policy Research Institute, 2009).
[43] Nick Hepworth and Marisa Goulden, "Climate Change in Uganda: Understanding the Implications and Appraising the Response," (Edinburgh: LTS International, 2008).
[44] Sumaya Ahmed Zakieldeen, "Adaptation to Climate Change: A Vulnerability Assessment for Sudan," in *The gatekeeper series* (London, UK: International Institute for Environment and Development, 2009).
[45] Hepworth and Goulden, "Climate Change in Uganda: Understanding the Implications and Appraising the Response."
[46] M. Goulden, D. Conway, and A. Persechino, "Adaptation to Climate Change in International River Basins in Africa: A Review," *Hydrological Sciences* 54 no. 5 (2009): 7.

also expected to increase the occurrence of extreme events like floods and droughts, to which the countries are very vulnerable (Tab. 2).

5 The adaptive capacities to climate change of the Nile Basin countries

The sensitivity to possible changes in environmental conditions in the Nile River Basin due to climate change will place a stress on the societies in the riparian countries, which adds to the challenges posed by demographic changes and economic development. However, adaptation to climate change is possible at different levels. While autonomous adaptation, e.g. farmers shifting sowing dates or crop types, is to some degree already occurring, large-scale challenges and especially those related to transboundary water resources are likely to be best addressed by planned adaptation at the national level, generally in conjunction with development mechanisms independent of climate change.

The adaptive capacity of a country is an indicator of the degree to which a society is able to adjust to changes in environmental conditions. It is defined as the ability to take measures in response to or in preparation for the effects of climate change. These measures can be directed towards minimizing harm, compensating for negative impacts or utilizing positive effects. Dimensions of adaptive capacity are the availability and distribution of resources, the range of available technological options, human and social capital, institutional structures and information management[47].

In this section, we discuss these dimensions of adaptive capacity in the context of existing pressures and the transboundary water distribution in the Nile countries. After focusing on the availability of natural resources (arable land and water) and population growth, the level of development is discussed in the context of technological options as well as human and social capital. Institutional structures and information management are related

[47] Gary Yohe and Richard S. J. Tol, "Indicators for Social and Economic Coping Capacity: Moving toward a Working Definition of Adaptive Capacity," *Global Environmental Change* 12, no. 1 (2002).

to governance and stability. Additionally, we have a closer look at cooperative water management as a mean to increase basin-wide adaptive capacities through transboundary cooperation. It should be kept in mind that adaptive capacity is not static but can change depending on changes in the different dimensions, which also influence each other.

5.1 Natural resource availability

Arable land and water resources in the Nile region are a constraint not only on adaptive capacity but also on economic development. This is because of their limited availability and the already considerable utilization pressure. A comparison of the available renewable water and arable land resources for key countries of the Nile Basin reveals substantial differences in resource endowments between the riparians (Tab. 3). While resources in the upstream states appear to be more abundant, they are underutilized at this point due to low level of development.

At the same time, these limited resources are under pressure from degradation and pollution. Human-induced land degradation is mostly caused by erosion stemming from overgrazing and deforestation[48]. While industrial pollution is restrained due to limited industrial development, municipal pollution from untreated sewage affects water resources to a much larger degree. In Egypt, intensive agriculture leads both to chemical deterioration of land as well as to water pollution from fertilizers and pesticides. Furthermore, salinization of soils from extensive irrigation is a problem.

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[48] Bo Appelgren, Wulf Klohn, and Undala Alam, "Water and Agriculture in the Nile Basin," in *FAO Miscellaneous Papers* (Rome2000); Mohamed Hamouda, A., Mohamed M. Nour El-Din, and Fawzia I. Moursy, "Vulnerability Assessment of Water Resources Systems in the Eastern Nile Basin," *Water Resources Management* 23(2009).

Table 3: Land and water resources available to key countries of the Nile River Basin[49]. The water dependency ratio refers to the percentage of transboundary water among the entire available renewable water.

	Egypt	Sudan	Ethiopia	Uganda
Available arable land [million ha]	2.88	20.16	13.95	6.60
Total renewable water [km^3/a]	57.3	64.5	122.0	66.0
Water dependency ratio [%]	96.86	76.92	0.00	40.91
Total water withdrawal [% of total renewable water]	119.0	57.6	4.6	0.5
Malnourishment [% of population][50]	no data	22	41	22
Irrigated land [% of the potential in Nile River Basin][51]	69.64	3.2	3.42	4.46
Installed HEP [% of potential]	83.31	3.33	1.37	3.6
Access to electricity [% of population][52]	98	30	15	8.9

The pressure on natural resources is strongly exacerbated by population growth, which is high in all Nile countries, further increasing the challenge of adaptation. By 2050, it is expected that the population of Egypt increases by a factor of 1.5. The growth factors of Ethiopia (1.7), Sudan (2.1) and Uganda (2.7) are even higher[53]. This will lead to increasing demands for water and food, as well as for employment opportunities, since both the working age population and the population living in urban areas are increasing simultaneously. Note that this is not even an extreme scenario but rather a moderate projection among several plausible trends.

A possibility to assess specifically the water availability in the Nile River Basin is the utilization of the Falkenmark water stress index[54]. This indicator defines hydrological water scarcity in categories of the available water per capita. If the amount of water available in a country drops below 1700 m^3 per capita, the country is considered to experience “water stress”. If the water availability even drops below 1000 m^3 per capita, the country experiences

[49] FAO, "Aquastat Main Country Database," http://www.fao.org/nr/water/aquastat/main/index.stm; World Bank, "World Development Indicators 2012," http://data.worldbank.org/data-catalog.
[50] FAO, "Faostat Online Statistical Service," faostat.fao.org.
[51] Salah El-Din Amer et al., "Sustainable Development and International Cooperation in the Eastern Nile Basin," *Aquatic Sciences - Research Across Boundaries* 67, no. 1 (2005). and references therein.
[52] World Resources Institute, "Earthtrends Database," http://earthtrends.wri.org/.
[53] Population Division United Nations Department of Economic and Social Affairs, "World Population Prospects: The 2010 Revision," (New York, NY: United Nations Department of Economic and Social Affairs, Population Division, 2011).
[54] Malin Falkenmark, Jan Lundqvist, and Carl Widstrand, "Macro-Scale Water Scarcity Requires Micro-Scale Approaches," *Natural Resources Forum* 13, no. 4 (1989).

"water scarcity". Based on this differentiation of the individual scarcity levels, Egypt currently can be classified as water scarce (678 m^3 per capita in 2010), Sudan and Ethiopia are water stressed (1436 and 1493 m^3 per capita in 2010 respectively) and only Uganda has relative water sufficiency (1953 m^3 per capita in 2010)[55]. If constant amounts of available water are assumed, the increasing population in the Nile River Basin will lead to a state of water scarcity in the countries of Sudan, Uganda and Ethiopia by 2030 (Fig. 4). Also, the already existing current water scarcity in Egypt will worsen to become a severe water scarcity. The amount of water consumed per capita and year is a function of the level of development of the different countries. The general trend is that greater the degree of development, the larger the amount of water consumed by each individual. However, this does not necessarily hold for higher developed countries anymore, as stronger sustainability concerns can lead to larger water savings[56].

5.2 Level of development

Human and social capital as well as technology options strongly depend on the level of development, which is very different across the Nile River Basin. The Human Development Index (HDI) is used here as a basic indicator for the degree of development in each country. The HDI classifies Egypt as medium-developed (HDI=0.62, rank=101), while Sudan (HDI=0.379, rank=154), Ethiopia (HDI=0.328, rank=157) and Uganda (HDI=0.422, rank=143) are low developed countries[57]. This highlights the asymmetry that exists in the Nile River Basin: the country with the highest level of development lies in that part of the region that has the most limited water availability, but it also has the highest exploitation potential. In contrast, the parts of the Nile River Basin, in which much more water is

[55] FAO, "Aquastat Main Country Database."; United Nations Department of Economic and Social Affairs, "World Population Prospects: The 2010 Revision."
[56] H. Zhang, "Nine Dragons, One River: The Role of Institutions in Developing Water Pricing Policy in Beijing, Prc" (McGill University, 1999).
[57] United Nations Development Programme, *Human Development Report 2011 - Sustainability and Equity: A Better Future for All* (New York, NY: United Nations Development Programme, 2011).

available, are only sparsely developed and so far have made limited use of their water resources. This is already changing as the upstream countries intensify their own development efforts, which coincides with an increase in water demand of their own.

Table 4: Indicators of development[58]. The land area is provided for better assessment of the road network in comparison to the size of the country.

		Egypt	Ethiopia	Sudan	Uganda
Infrastructure	Land area [million km^2] (2010)	0.99	1.00	2.38	0.20
	Total road network [1000 km]	92.37 (2004)	36.47 (2004)	11.90 (2001)	70.75 (2003)
	Vehicles per 1000 people (1996)	29.6	1.4	10.4	4.2
	Improved sanitation facilities [% of population with access] (2008)	94	12	34	48
	Internet users [per 100 people] (2010)	27	1	..	13
Education & innovation	Literacy rate (all adults) [%]	66.4 (2006)	35.9 (2007)	60.9 (2000)	73.6 (2007)
	Gross enrolment in secondary education [%]	88 (2004)	30 (2007)	33 (2007)	18 (2005)
	Patent applications (residents) (2007)	516	12	3	8
Economy	GDP [bio constant 2000 US$] (2010)	160.26	18.32	22.82	12.61
	GDP growth [annual %] (2010)	5	10	4	5
	Life expectancy at birth [years] (2009)	73	58	61	53

The currently low levels of development in upstream countries not only become apparent in an overall indicator such as the HDI but are also reflected in more specific indicators such as the availability of infrastructure and indicators for education representing social capital for adaptive capacity as well as technological options. These are mostly low in Sudan and particularly low in Ethiopia, and Uganda (Tab. 4). However, development is accelerating in the upstream countries as well so that the overall level of development in the Nile River Basin is likely to increase considerably in the decades to come.

The comparatively low levels of development in the upstream states are at least partly related to the high level of climate sensitivity – the climate-sensitive agricultural sector is an

[58] World Resources Institute, "Earthtrends Database."; World Bank, "World Development Indicators 2012."

important contributor to the countries' GDP and the ability to manage the water resources, reflected by the levels of irrigated agriculture as well as plain withdrawals, is low with the exception of Egypt (Tab. 3). Both factors constitute a feedback loop: low levels of development constitute a low ability for economic improvements or water management. At the same time high climate sensitivity hinders development. However, development becomes more and more an imperative in the upstream countries, especially due to the continued population growth. At the same time it also becomes more feasible due to increased stability and effectiveness of institutions.

5.3 Institutions and political stability

Development and an increase in adaptive capacity are not only dependent on the economic boundary conditions but also on the setting in which the societal progress takes place. Political stability, good governance and functioning institutions are key prerequisites for development and for building up a country's adaptive capacity to deal with climate change issues.

5.3.1 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. The region is historically one of the most unstable on the whole African continent, even though there have been very few interstate wars, the last one being the costly 1998-2000 Ethiopian-Eritrean war, where peace is still insecure. However, in all Nile Basin countries, multiple intrastate wars and minor conflicts have and are still taking place. Only the most important ones for the four focus countries can be named here.

Egypt has been more stable than its neighbors during the past decades (Fig. 5); however there have been intra- and sub-state conflicts with radical Islamic groups, interreligious conflicts and most notably the events of the Arab Spring, resulting in regime change in February 2011 and still flaring protests. In Sudan, instability and conflict is prominent in most parts of the country, particularly important are the Darfur and South Sudan conflicts, which were officially concluded with peace agreements in 2005/2006 and the independence of South Sudan in 2011. However, violence is still ongoing in both cases. Ethiopia is the scene of multiple low-level conflicts between the government and various ethnic rebel groups, especially in the south-east of the country. Uganda has been the stage of an almost uninterrupted conflict between the government and various rebel groups since 1978. Fighting however has decreased substantially since the 1990s. Since 2002, the Lord’s Resistance Army (LRA) is the only rebel group remaining; but it is not active in Uganda at present.

These developments are reflected in the Political Stability Index (Fig. 6a), which is consistently low or even dropping, with the exception of Uganda.

5.3.2 Institutions & governance

Effective and reliable institutional structures and good governance are important for adaptive capacity since they provide the space for gathering, synthesizing and distributing relevant information, for long-term planning and infrastructure for large as well as support for small adaptation activities. The status of governance and functionality of institutions in the Nile Basin countries can be assessed using the World Governance Indicators[59], most importantly those for government effectiveness, control of corruption and voice and accountability (Fig. 6 b,c,d). Government effectiveness refers to the quality of public services

[59] World Bank, "Worldwide Governance Indicators," http://info.worldbank.org/governance/wgi/index.asp.

and the degree to which it is independent from political pressure[60]. Voice and accountability is an indicator for the extent to which citizens are free to choose their government and to express their opinions. Control of corruption is a proxy for the degree to which public power is utilized for private advantages.

For all countries, these indices are rather low in the past two decades, though improvements can be seen e.g. for Ethiopia in government effectiveness and control of corruption, or for Uganda in voice and accountability. Nonetheless, this constantly low level of good governance and resulting institutional ineffectiveness is clearly a strong indicator for rather low adaptive capacity.

5.4 Cooperative water management

Due to the important role of the Nile River for the riparian countries, the management system of the river is also part of the level of adaptive capacity. Because of its transboundary nature and the high diversity of geographic and environmental conditions in the riparian countries, river flow is highly sensitive to both climatic and variability changes and human use and impact. At the same time, best use of comparative advantages in natural and societal conditions can be made through cooperation, increasing the basin-wide level of adaptive capacity. Even though there are already several cooperative water projects in the Nile River Basin such as the ones listed on the website of the Nile Basin Initiative, the countries are still far from an efficient basin-wide water management system. Existing comparative advantages include e.g. HEP and livestock in Ethiopia, agriculture in Sudan, the cash crops and financial investment capabilities of Egypt, a reduction of evaporation losses by storing water upstream

[60] Daniel Kaufmann, Aart Kraay, and Massimo Mastruzzi, "Governance Matters Viii: Aggregate and Individual Governance Indicators, 1996-2008," *SSRN eLibrary* (2009).

in Ethiopia rather than downstream in Sudan and Lake Nasser, and increased trade of electricity, food and other market goods[61].

Ethiopia has been called the “water tower of Eastern Africa”[62] because of its considerable rainfall levels giving rise to 14 major rivers flowing from its high elevations to neighboring countries. These large elevation differences also give it a large potential for HEP, which is only starting to be developed now, through national efforts in Ethiopia with international (largely Chinese) support but without intra-basin cooperation. Intra-basin power trading is seen as a promising tool to foster cooperation and development and is an important part of NBI activities, as can be seen from the recent “Study of power trade opportunities in the Nile Basin”[63].

A further advantage of dams in Ethiopia with its higher elevations and cooler temperatures is the lowered rate of evaporation, especially compared to Lake Nasser in the Sudanese-Egyptian desert. Multiple studies have shown that this could increase the total water availability in the Nile River Basin[64]. Finally, water storage in Ethiopia would also help Sudan to further develop its potential to be the “bread basket of Africa”[65], related to its large amounts of arable land. It is far from realizing this potential, partially because of water constraints for the necessary irrigation.

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[61] Dennis Wichelns et al., "Co-Operation Regarding Water and Other Resources Will Enhance Economic Development in Egypt, Sudan, Ethiopia and Eritrea," *International Journal of Water Resources Development* 19(2003); Simon A. Mason, *From Conflict to Cooperation in the Nile Basin. Interaction between Water Availability, Water Management in Egypt and Sudan, and International Relations in the Eastern Nile Basin* (Zurich: Swiss Federal Institute of Technologie ETH Zurich, 2004); Dale Whittington, "Visions of Nile Basin Development," *Water Policy* 6, no. 1 (2004).

[62] Ashok Swain, "Ethiopia, the Sudan, and Egypt: The Nile River Dispute," *The Journal of Modern African Studies* 35, no. 04 (1997).

[63] NBI, "Inaugural Study of Power Development Options and Power Trade Opportunities in the Nile Basin Completed," (2012), http://www.nilebasin.org/newsite/index.php?option=com_content&view=article&id=117%3Ainaugural-study-of-power-development-options-and-power-trade-opportunities-in-the-nile-basin-completed&catid=40%3Alatest-news&Itemid=84&lang=en

[64] Giorgio Guariso and Dale Whittington, "Implications of Ethiopian Water Development for Egypt and Sudan," *International Journal of Water Resources Development* 3, no. 2 (1987); Q. Goor et al., "Optimal Operation of a Multipurpose Multireservoir System in the Eastern Nile River Basin," *Hydrology and Earth System Sciences* 14(2010).

[65] Zakieldeen, "Adaptation to Climate Change: A Vulnerability Assessment for Sudan."

Clearly, effective basin-wide water management could not only help to increase future adaptive capacity to climate change but also to address the multiple challenges facing the basin today in terms of food demand and development needs.

5.5 Summary

Two main conclusions can be drawn from the two previous sections. First, bringing together the discussions of the three dimensions of vulnerability of the key Nile Basin states, their exposure and sensitivity to climate change is high while their adaptive capacity is currently rather limited. This leads to the conclusion of high vulnerability to climate change in these states, which is in agreement with findings by Brooks and others[66] who measured national vulnerability using a set of eleven indicators and rated Ethiopia and Sudan among the most vulnerable and Uganda among the moderately to highly vulnerable countries. In contrast, Egypt's vulnerability is somewhat lower due to its higher level of development, but it also faces the most severe challenges of the riparian countries, partly due to its great dependence on the Nile waters[67].

Second, the Nile River Basin will likely be strongly affected by climate change, though the direction of this change is unclear at this point, and it is already challenged by a highly variable climate today. This adds to a large number of challenges for the countries of the basin and interacts with changing power relations between riparian states and simmering tensions over a new basin-wide agreement that would change the status quo of water allocations. Potential pathways towards more interstate conflict or more transboundary cooperation resulting from this interaction will be assessed in the following section.

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[66] Nick Brooks, W. Neil Adger, and P. Mick Kelly, "The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation," *Global Environmental Change Part A* 15, no. 2 (2005).

[67] Janpeter Schilling et al., "Climate Change, Vulnerability and Adaptation in North Africa with Focus on Morocco," *Agriculture, Ecosystems and Environment* doi 10.1016/j.agee.2012.04.021(2012).

6 Discussion: Can climate change potentially affect the balance of power in the Nile River Basin?

Based on the assessment framework in Fig. 2, a network of possible pathways towards conflict or cooperation can be deduced (Fig. 7).

They are summarized in Figure 8 for a better overview and discussed in the following. The first focus is on the impacts of changes in water availability, and then the interaction of climate change with cooperation options is explored.

6.1 Changes in Nile water availability

A projectable water supply in the entire Nile River Basin is of substantial importance for water development projects, especially with respect to transboundary effects and development in general but also for transboundary interactions. Water supply is determined by Nile flow but no reliable predictions can currently be made about the impacts of changes in Nile flows in the future. Therefore, all three possible options are discussed here – flow reduction, flow increase and stable average flow with increased variability – together with possible impacts on conflict or cooperation. Furthermore, water supply is affected by changes in water demand due to the extra dimensions of development and population growth. Advances in development tend to increase the per capita consumption of water. Population growth also adds to the pressure on the water resources in the Nile River Basin. These further influences are addressed separately.

6.1.1 Reduction of Nile flow

A reduction in total flow would increase water scarcity for the entire Nile River Basin. For the upstream countries this would increase the dependency on Nile water since in that case probably also their other water sources would be diminished. The downstream countries would be hard pressed to maintain the current status quo. Even if their allocations remained unchanged, the total water availability would be reduced and they would have to adapt to that altered situation, e.g. by implementing changes in the agricultural sector, increasing water efficiency and other means like virtual water imports[68]. Overall, the implementation of projects requiring large investments such as HEP dams may become unprofitable. The relation of irrigation water demand to supply would become worse, endangering food supply. Development could be hampered, unless efficient measures are taken to adapt.

Lower water availability could intensify today's' conflict potential, increasing the perceived need for unilateral actions to increase Nile water use upstream and defend historic allocations downstream. On the other hand states could seek more efficient adaptation through cooperation, using the available scarce water most efficiently through basin-wide water management and the exploitation of the advantages described in Section 5.5. For Egypt and Sudan, this would mean joining the CFA. However, even in the cooperative case it could be much more difficult to reach an agreement under tighter conditions than those existing today.

6.1.2 Increased Nile flow

An increase in total flow, while increasing total water supply throughout the Nile River Basin and therefore leaving more water to distribute for the various needs, would not be without problems either. On the one hand, it would be easier to cooperate since additional water could be used by the upstream countries while Egypt could maintain its current quota. This would still require changes to the existing treaty, which divides the Nile water

[68] These are already extensive in Egypt, up to 32 km^3/year. This is more than 50% of its Nile water allocation (55.5 km^3/yr) (Allan, "Nile Basin Asymmetries: A Closed Fresh Water Resource, Soil Water Potential, the Political Economy and Nile Transboundary Hydropolitics."). Since such imports require financial resources, this adaptation option is difficult to realize for upstream states because of their lower level of economic development.

percentage-wise between Egypt and Sudan and includes regulations for dividing any increases as well[69]. This holds a similar conflictive potential as can already be seen today.

On the other hand, challenges may arise since a higher flow might overwhelm the capacities of dams (existing and future ones unless they take this possibility into account). Furthermore, infrastructure on the river banks might be endangered and siltation may increase. Climate-proofing of infrastructure, i.e. the retrofitting to ensure durability even under increased stress due to altered environmental conditions, is important in that regard. Therefore, also in this case a strong incentive for cooperation over water projects exists to ensure the efficient use of the water resources.

6.1.3 Stable Nile flow, increased variability

An increase in variability, especially of precipitation and therefore of Nile flow, is the most securely predicted impact of climate change. It will also affect flow in the previous two scenarios, however, for better separation of effects it is discussed here, since it definitely also constitutes a threat to the water supply in the Nile River Basin even if the total amount of water available remains unchanged. Both floods and droughts as the extreme events of variability are large dangers to human wellbeing through their effects on agriculture, infrastructure, food supply and livelihoods. From a basin-wide point of view, more floods and droughts make dam operations more challenging, perhaps sometimes even non-viable. The cost-benefit ratio of large dams under climate change is also questionable[70]. To the very least a good cooperation in the management of dams is necessary, if transboundary effects like significant lowering of water flow or destruction through sudden flooding are supposed to be minimized. A basin-wide early-warning system would also be highly beneficial.

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[69] "Agreement between the Government of the United Arab Republic and the Government of Sudan," (Cairo1959).

[70] P.J. Block, Strzepek, K., Rajagopalan, B. , "Integrated Management of the Blue Nile Basin in Ethiopia," in *IFPRI Discussion Paper* (IFPRI, 2007).

Disasters can be facilitators for cooperation, if in the aftermath of such events breakthroughs in negotiations between countries occur[71]. However, such disasters already happen on a frequent basis in the Nile River Basin without having any positive impact on interstate relations. It might be possible that a higher frequency or strength of floods and droughts could overwhelm Egypt's adaptive capacity by either overflowing or strongly reducing the water level in Lake Nasser. An example of this possibility were prolonged droughts in the 1980s, when in 1988 Egypt barely avoided a major water shortage[72]. This could convince Egypt to accept more cooperation and develop closer relations between Sudan and Ethiopia, which could become attractive for Sudan as it suffers greatly from Nile floods already. On the other hand, conflict potential could arise spuriously, in the case of really extreme events if cooperation failed to exist or to prevent effects.

Clearly, changes on the supply side could be managed. But they probably require increased levels of cooperation, including the joint management of dams. Insisting on the status quo will put Egypt at an increased risk and, in case of large reductions in flow; it might even be tempted to apply force on its neighbors to protect their water supply.

6.1.4 Changing water demand as an additional dimension

Water demand in the Nile Basin will go up due to population growth and development needs. This will be exacerbated by rising temperatures and increasing water demand in all sectors. Increasing water scarcity from reduced Nile flow would be further intensified, while flow increases would be reduced again, possibly balanced out or even turned into net decreases. Greater demand also negatively interacts with greater variability, increasing negative consequences of droughts. Increased pressure on the water resources can strengthen the arguments of proponents of more cooperation to divide access to the resource in a more

[71] Pieter Huisman, Joost de Jong, and Koos Wieriks, "Transboundary Cooperation in Shared River Basins: Experiences from the Rhine, Meuse and North Sea," *Water Policy* 2, no. 1-2 (2000).
[72] Conway, "From Headwater Tributaries to International River: Observing and Adapting to Climate Variability and Change in the Nile Basin."

efficient way. However, higher demand and the increased scarcity of water can also serve as an argument to follow a more conflictive pathway. In the worst case it could lead to stronger efforts in the upstream states to use Nile water while at the same time strengthening Egypt's point of view that it is unable to reduce its allocation, increasing the likelihood for conflictive responses. While the argument for more cooperation is also intensified by an even greater gap between demand and supply, the compromises any riparian would have to make for cooperation are also larger and ultimately may be too much to bear.

Even though both the cooperation and the conflict path are possible under climate change, the current status of water allocation in the Nile River Basin has to be taken into account in the discussion as well. Currently, there are a number of cooperative projects whose viability is discussed in the subsequent section.

6.2 The effect of climate change on cooperation schemes

6.2.1 Technical projects

Climate change can affect existing and planned cooperation projects between the countries in the Nile River Basin positively or negatively. Current cooperation is mostly technical but with the goal to share any possible benefits. Examples of technical cooperation can be found in the areas of electricity, irrigation and flood protection[73]. All such infrastructure measures are related to the river, like dam construction and operation. Therefore they are highly susceptible to any changes in the river flow. It is therefore of great importance that such projects are "climate proof" so that they can be completed even in times of changing climatic conditions. Development plans that are made on the basis of current climatic conditions and long-term records of the past may not be suitable under climate change[74].

[73] Goulden, Conway, and Persechino, "Adaptation to Climate Change in International River Basins in Africa: A Review."
[74] Paul Christopher D. Milly et al., "Climate Change: Stationarity Is Dead: Whither Water Management?," *Science* 319, no. 5863 (2008).

While irrigation schemes are important, a reduction of vulnerability includes a shift in importance from agriculture to other sectors in order to decrease the countries' exposure to the impacts of climate change. This could go along with increased agricultural trade within the Nile River Basin, utilizing the most advantageous areas for agriculture. With respect to HEP and flood protection as tasks for dams it has been suggested that a combination of micro-dams and mini-HEP projects[75] and a few well-placed large-scale projects is likely to be quite advantageous. However, large gains in water availability due to reduced evaporation are then unlikely since the best locations for such dams are at rather low elevation[76]. In general, intensified trade between the riparians will lead to improved relations, stronger interdependencies and a decrease of the risk of conflict.

Clearly, technical cooperation and joined basin-wide water management increase the adaptive capacity of the entire Nile River Basin. However, unilateral technical adaptation measures to climate change can also increase conflict risk through direct impacts on the possibility for adaptation in other countries[77]. This is what currently happens in the Nile River Basin – unilateral water development projects are implemented without climate change serving as a motivation to take such action now. As climate change intensifies, the impacts of such projects on the other countries could be amplified and thus the motivation for armed conflict possibly be increased.

6.2.2 Cooperation Treaties

Climate change can influence the stability of cooperative agreements on transboundary water resources. A decrease in water flow can destabilize agreements, and

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[75] John Waterbury, *The Nile Basin - National Determinants of Collective Action* (New Haven and London: Yale University Press, 2002); Hepworth and Goulden, "Climate Change in Uganda: Understanding the Implications and Appraising the Response."

[76] Waterbury, *The Nile Basin - National Determinants of Collective Action*.

[77] Goulden, Conway, and Persechino, "Adaptation to Climate Change in International River Basins in Africa: A Review."

increases in variability could have either stabilizing or destabilizing effects[78]. Cooperation in terms of international arrangements and treaties seeks to benefit all parties involved to at least some degree without compromising individual positions to a larger degree. However, they can also be limiting or negative in a number of ways, for example with respect to transparency, data quality, equitability, environmental sustainability or implementation[79]. Treaties can be particularly restrictive with respect to the impacts of climate change if they do not provide enough flexibility to address the uncertainty in climate change predictions and the increasing variability expected[80]. In that case treaties can become ineffective, unsustainable or even counter-productive to adaptation. In order to make an agreement “climate-proof” four categories of regulations should be included: flexible allocation strategies and water quality criteria, provisions for extreme events, amendment and review procedures, joint management institutions[81]. In contrast, a fixed allocation mechanism is the least stable regime[82].

The key water treaty for the Nile River Basin that is still in effect today is the 1959 treaty between Egypt and Sudan. According to above criteria, this treaty can be considered to be relatively positive. While it has fixed allocations, there are mechanisms to change these for extreme events and changes in future demands. This could be considered a review procedure, which occurs in the framework of the Permanent Joint Technical Committee, a joint management institution. However, this agreement is obviously neither equitable nor inclusive, and when the review process was tested by a request from the upstream countries for the allocation of 5 km^3 in 1961, this request was rejected[83].

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[78] E. Ansink and A. Ruijs, "Climate Change and the Stability of Water Allocation Agreements," *Environmental and Resource Economics* 41 (2008).
[79] Elisabeth J. Kistin, "Qualifying Cooperation over Transboundary Waters" (paper presented at the Water Governance for Africa - The challenge of uncertainty and change, University of Bradford, 2006).
[80] Itay Fischhendler, "Legal and Institutional Adaptation to Climate Uncertainty: A Study of International Rivers," *Water Policy* 6, no. 4 (2004).
[81] Heather Cooley et al., "Understanding and Reducing the Risks of Climate Change for Transboundary Waters," (Oakland: Pacific Institute, 2009).
[82] Ansink and Ruijs, "Climate Change and the Stability of Water Allocation Agreements."
[83] Waterbury, *The Nile Basin - National Determinants of Collective Action*.

While Egypt's main interest is to uphold this agreement, Sudan increasingly is interested in developing its own economic potential. However, in order to do so much more water is needed than the amount allocated to Sudan in 1959[84]. The temptation of a closer cooperation with Ethiopia[85] could grow under changing environmental conditions, particularly with respect to flood control.

The CFA itself cannot be assessed with regard to being "climate-proof" since the text is not publicly available. If climate change was not taken into account, its long-term capacity to solve the problems of the Nile River Basin is greatly diminished, even if it comes into effect.

Right now, the basin in its entirety is far from being prepared for climate change due to the lack of a basin-wide agreement. However, the NBI can be seen as a positive factor to change this. While climate change has not yet been addressed in 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 the sharing of benefits has created capacities, which are useful also in the context of climate change mitigation and adaptation[86]. Currently, a concrete project is being developed to work on climate change impacts and adaptation within the NBI[87]. If the CFA entered into force, this could provide a very positive starting point to ensure the appropriate inclusion of the climate challenge into the work of the permanent Nile River Basin Commission. The future of the NBI is uncertain if Egypt and Sudan do not join the CFA as such a position considerably increases the difficulties to improve the adaptive capacities in all the countries of the Nile River Basin.

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[84] Cascão, "Changing Power Relations in the Nile River Basin: Unilateralism Vs. Cooperation?."
[85] Waterbury, *The Nile Basin - National Determinants of Collective Action*.
[86] Cooley et al., "Understanding and Reducing the Risks of Climate Change for Transboundary Waters."
[87] NBI, "Nile-Com Endorses Initiative to Address Climate Change Impacts and Adaptation in the Nile Basin," (2008), http://www.nilebasin.org/index.php?option=com_content&task=view&id=88&Itemid=70.

7 Conclusion

Climate change affects the causal network that links transboundary water availability and water use to human wellbeing in several ways: It also shapes actions on water development with transboundary consequences and therefore the relations between the riparian states. Assessments of the action pathways allow for the deduction of scenarios leading to greater conflict as well as greater cooperation. This is due to the high but also variable vulnerability of Nile Basin states to climate change. While a direct link between changing climatic conditions and violent conflict is unlikely, the indirect effects are possibly more significant.

Cooperation can be hindered or facilitated by climate change. On the one hand, cooperation appears to be more important than ever, and efficient adaptation can probably only be reached under strong cooperation, particularly for increasingly variable conditions. While higher flows may reduce the barriers to cooperation (unless they are offset by higher demand); the situation would become more difficult for lower flows. Although in this case the barriers towards cooperation are increased, at the same time there is a higher need for cooperation to make most efficient use of available water resources. Research on water conflicts in the past decade shows that there is considerably more cooperation over transboundary water resources than conflicts[88].

Cooperation is essential for a basin-wide increase of adaptive capacity and therefore reduction of vulnerability to climate change. Until 2011 it seemed very unlikely that cooperation could be achieved between upstream countries and Egypt unless much higher incentives are created. After the events of the Arab Spring, the first actions and rhetoric of the new Egyptian leadership point towards a possible softening of the position and increased

[88] Aaron T. Wolf, "Conflict and Cooperation Along International Waterways," *Water Policy* 1, no. 2 (1998); S. Yoffe, A. T. Wolf, and M. Giordano, "Conflict and Cooperation over International Freshwater Resources: Indicators of Basins at Risk," *Journal of the American Water Resources Association* 39, no. 5 (2003); Ashok Swain, "Mission Not yet Accomplished: Managing Water Resources in the Nile River Basin," *Journal of International Affairs* 61, no. 2 (2008).

interest in good relations with the basin neighbors. However, it is too early to really assess if this is a lasting change in position. The independence of South Sudan could be another game changer in the basin, as it is of large importance for White Nile contributions to the Main Nile and it could ally itself either with upstream or downstream states. So far no conclusive moves have been made and the new government might just wait before taking sides and address other, more pressing issues first.

Clearly, incentives for cooperation are still important at this point, as they can support the positive impact these recent events could have on transboundary relations. These could include strong outside encouragement or even pressure, as well as conditional external financial support[89]. One particular incentive for Egypt to join a cooperation scheme on the Nile water could be its increasing dependence on information about rainfall and flows upstream in order to efficiently manage the Aswan High Dam and prepare for floods and droughts. On the other hand, climate change impacts could also affect the developing capacities of the upstream countries, which currently enable them to challenge Egypt's hydro-hegemony. This would therefore reduce the incentive for Egypt to cooperate with its neighbors about the allocation of the water from the Nile.

Any basin-wide treaty can only be sustainable under climate change if it includes special provisions for altered environmental conditions. Flexibility is a key ingredient for agreements, infrastructure, and institutions. However, flexibility in agreements can endanger enforceability and reduce reliability of expected water flows. This trade-off is part of the reason why so many agreements are formulated in rather general terms[90].The best solution is water allocation based on percentages. These are concrete values that can be enforced. At the same time it is also possible to adapt to changing flows. However, such provisions can only

[89] Wolf, "Conflict and Cooperation Along International Waterways."
[90] A. Drieschova, M. Giordano, and I. Fischhendler, "Governance Mechanisms to Address Flow Variability in Water Treaties," *Global Environmental Change-Human and Policy Dimensions* 18, no. 2 (2008).

be successful if transparent conflict resolution mechanisms are installed to address any disagreements that might occur.

The most likely and immediate impact of climate change on the riparian relations is its instrumentalization either by a securitization of climate change itself, or by an enhanced securitization of water. Such development is a considerable threat to cooperation in the Nile River Basin as it promotes distrust among the riparians and emphasizes unilateral action rather than joint efforts to increase the adaptive capacities of all countries in the Nile River Basin to successfully deal with the implications of altered environmental conditions due to climate change.

Figure 1: The Nile River Basin showing the different vegetation zones. The independence of South Sudan is disregarded in this representation.

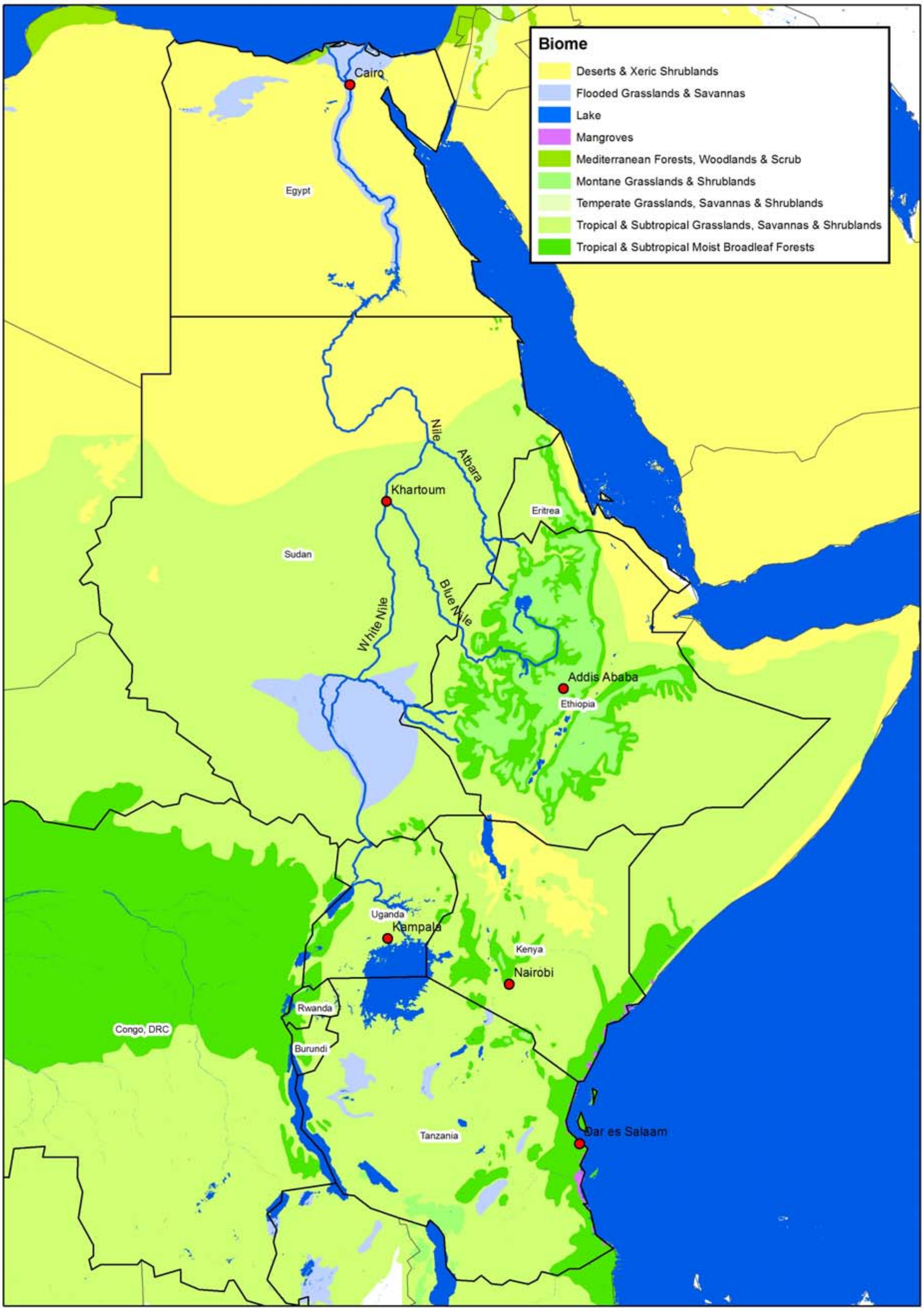


Figure 2: Schematic overview of the relationship between environmental change and societal stability.

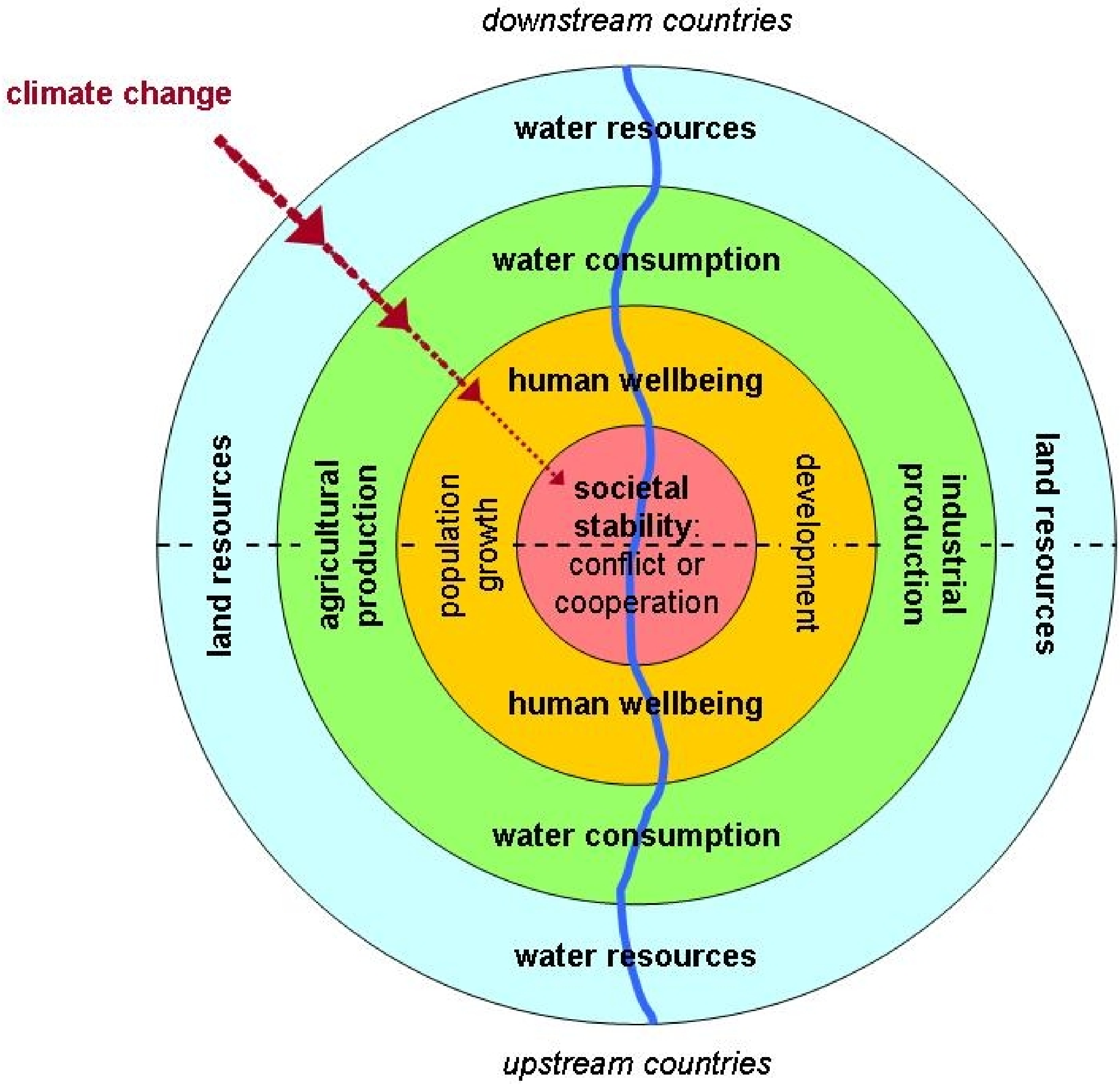
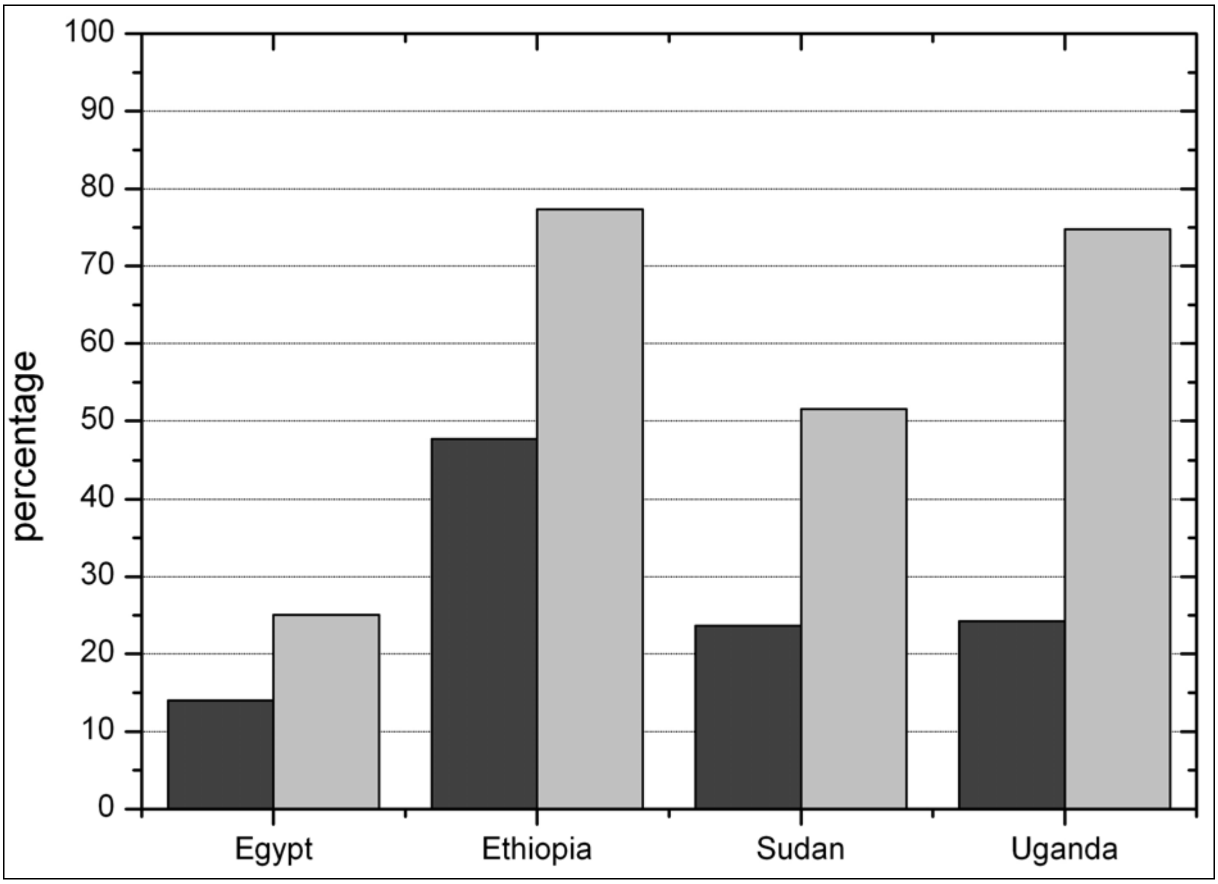
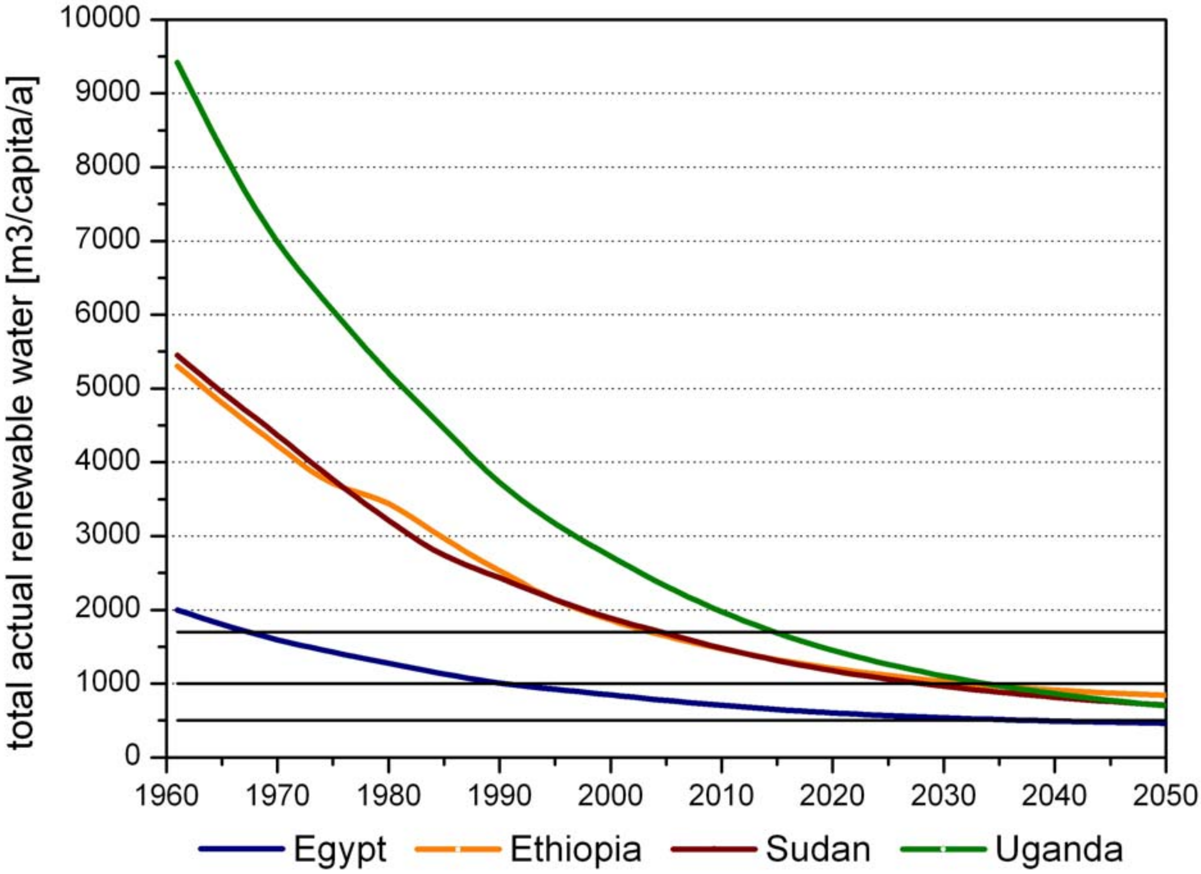


Figure 3: The importance of the agricultural sector[91]. Value added in % of GDP (dark grey) and agricultural labor in % of total economically active population (light grey) in 2010.



[91] FAO, "Faostat Online Statistical Service."

Figure 4: Expected increasing water stress in all Nile countries under the assumption of constant water availability[92]. The horizontal black lines indicate the Falkenmark thresholds for water scarcity: severe scarcity: < 500 m^3/capita annually, scarcity: < 1000 m^3/capita annually, stress: < 1700 m^3/capita annually[93] .



[92] "Aquastat Main Country Database."; "Faostat Online Statistical Service."

[93] Falkenmark, Lundqvist, and Widstrand, "Macro-Scale Water Scarcity Requires Micro-Scale Approaches."

Figure 5: The number of wars, minor armed conflicts and coups d'état 1975 – 2009. The latter only includes successful and attempted coups. Note: the negative scale on the y axes is for illustration purposes only. The actual values are the absolute value of the ones shown. Data source: (UCDP / PRIO 2010).

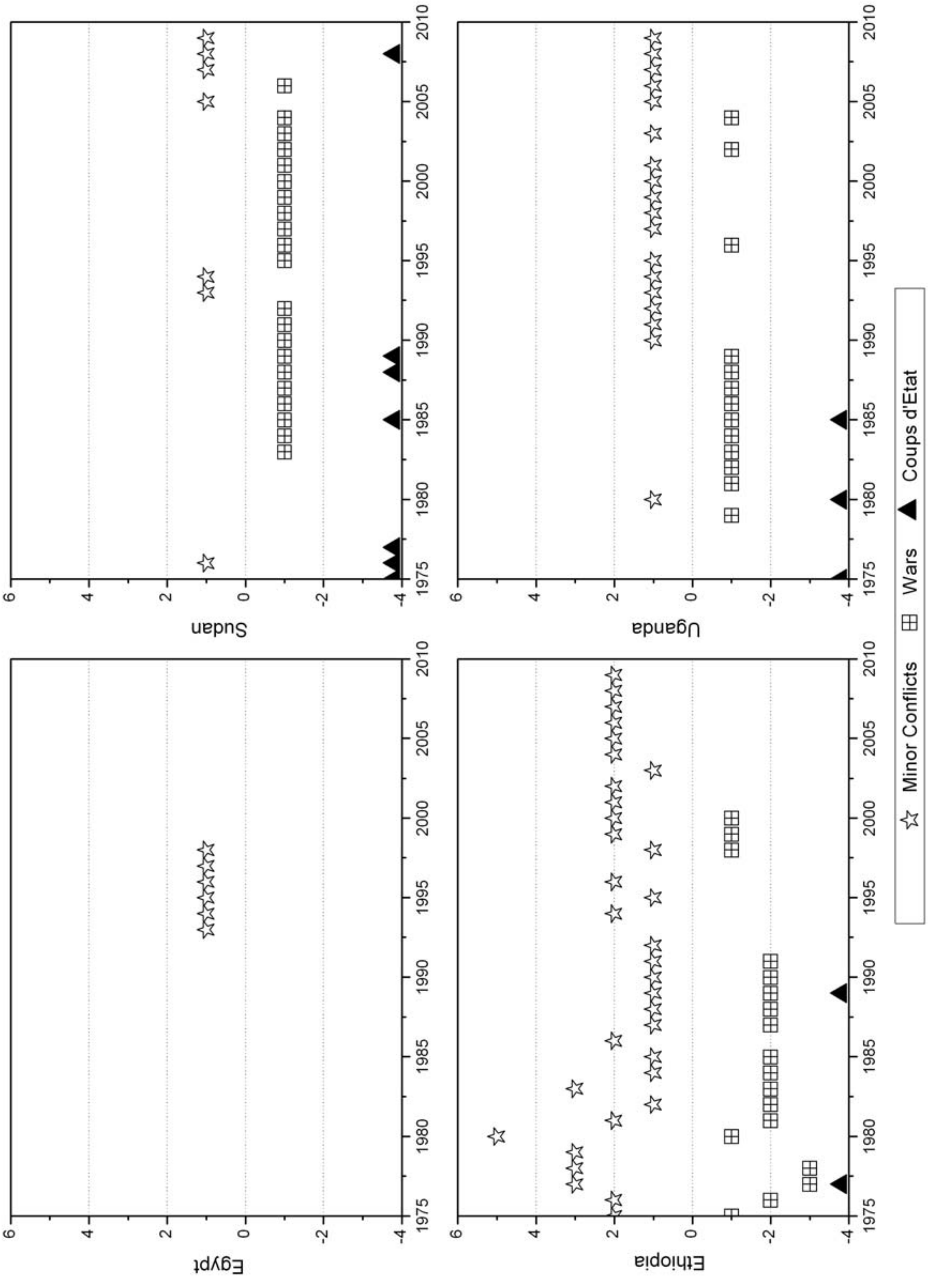
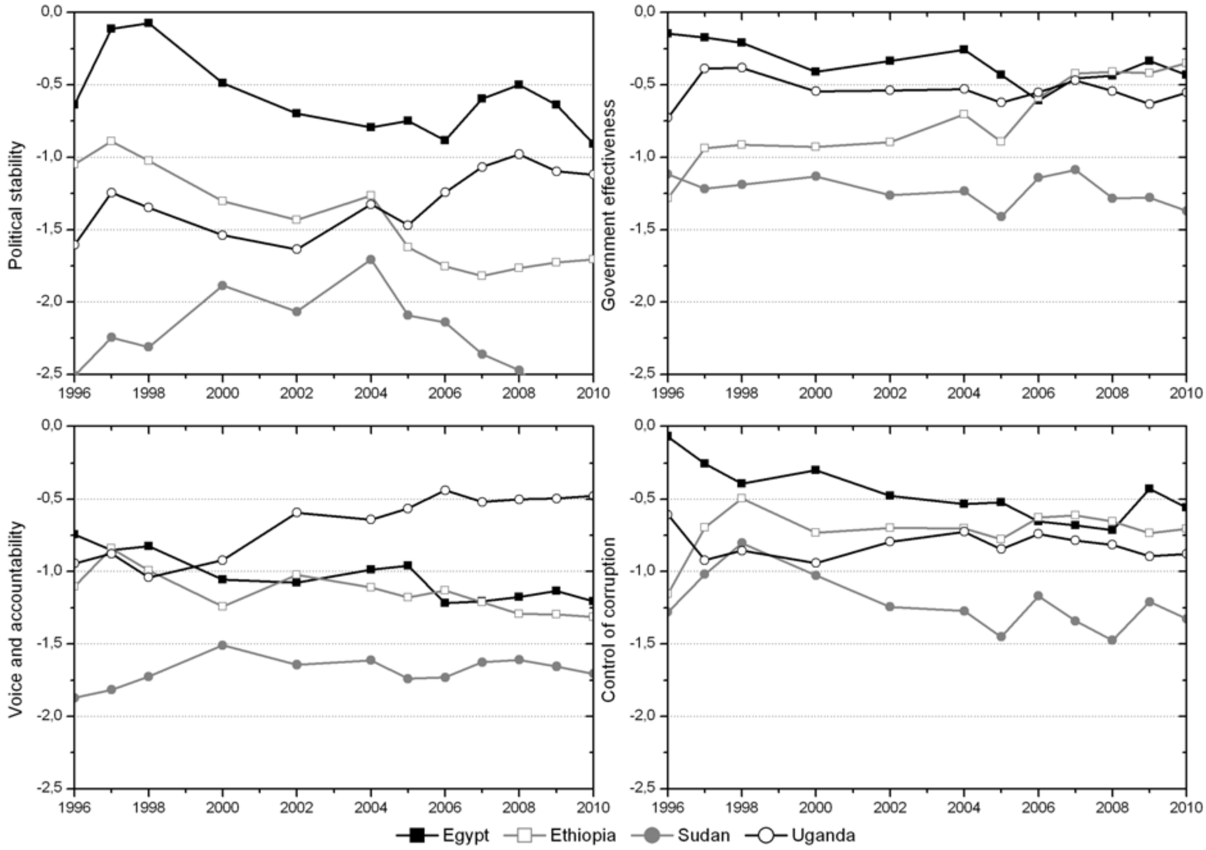


Figure 6: Indicators of political stability (a), government effectiveness (b), voice and accountability (c), and control of corruption (d) in key countries of the Nile River Basin[94]. Estimates of each quantity can range from –2.5 to +2.5.



94 World Bank, "Worldwide Governance Indicators."

Figure 7: Network of possible pathways linking impacts of climate change to conflict or cooperation.

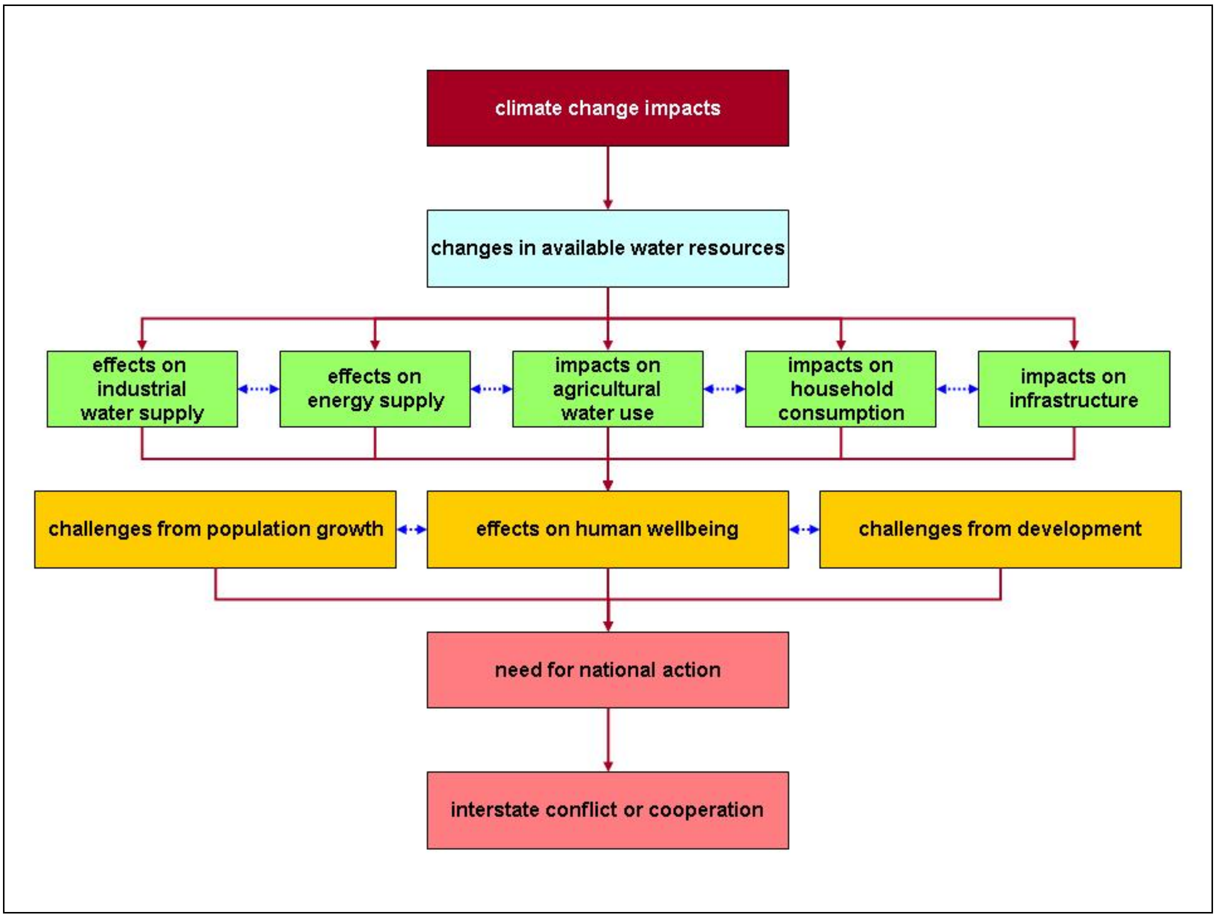
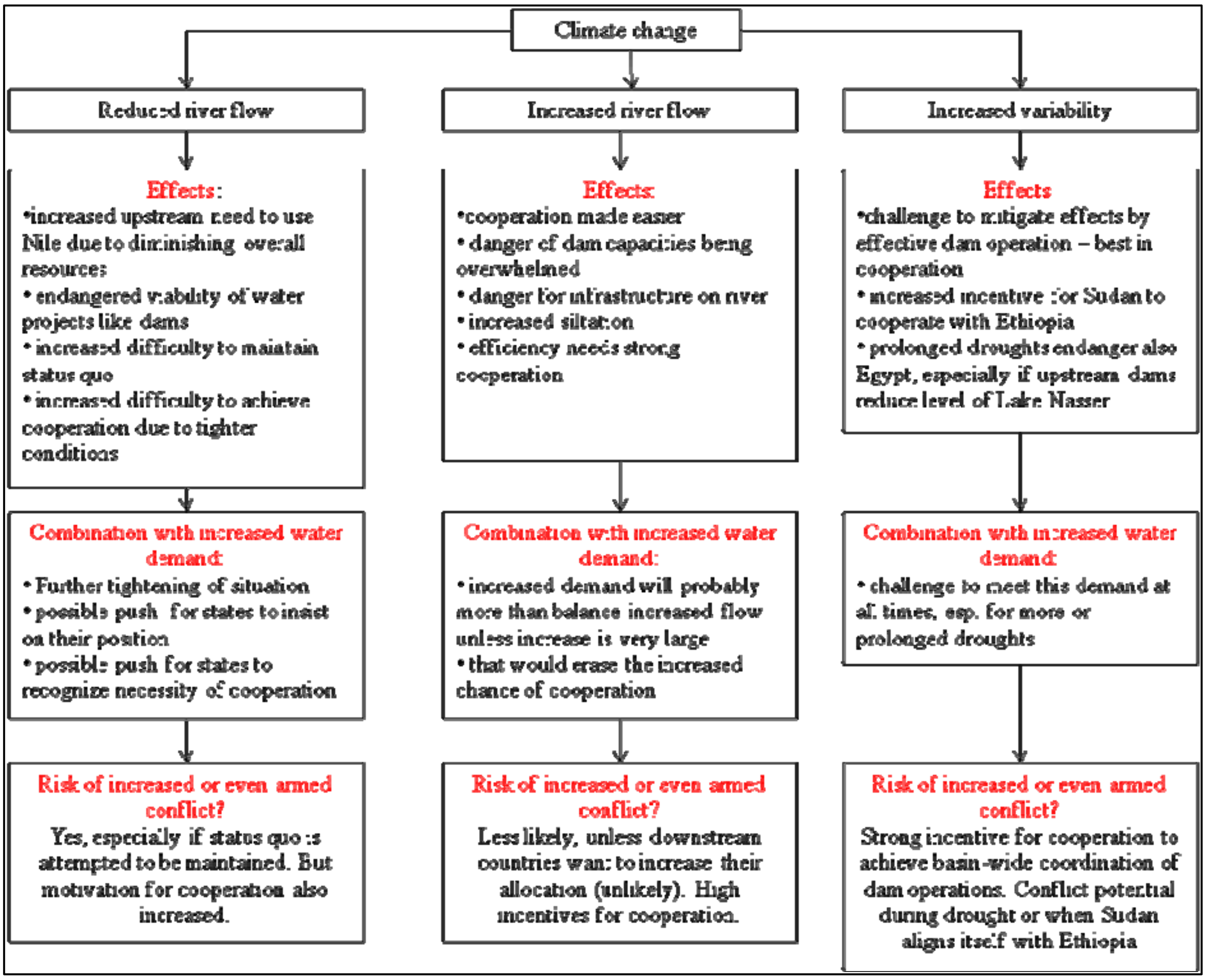


Figure 8: An overview of the effects of climate change on water supply and the link to the occurrence of conflict or cooperation, taking into account the likely increase in water demand due to climate change, population growth and development.



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