The Impact of Climate Change on Conflict and Cooperation in the Nile Basin

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by

Dr. Franziska Piontek
Schleiz, Germany

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Graders:
Prof. Dr. Jürgen Scheffran
Prof. Dr. Michael Brzoska

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List of Abbreviations

CGIAR	Consultative Group on International Agricultural Research
CFA	Comprehensive Framework Agreement
CINC	Composite Index of National Capabilities
CLISEC	Research Group Climate Change and Security, Hamburg University
CNA	Center for Naval Analyses
EAC	East African Community
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FEWS NET	Famine Early Warning Systems Network
GCM	General Circulation Model
GDP	Gross Domestic Product
HEP	Hydro-Electric Power
HDI	Human Development Index
HWSI	Hydrological Water Scarcity Index
ICESRC	International Covenant on Economic, Social and Cultural Rights
IPCC	Intergovernmental Panel on Climate Change
MENA	Middle East and North Africa
NATO	North Atlantic Treaty Organization
NBI	Nile Basin Initiative
NGO	Non-Governmental Organization
SWSI	Social Water Scarcity Index
TWINS	Transboundary Water Interaction Nexus
UN	United Nations
UNEP	United Nations Environment Programme
UNSC	United Nations Security Council
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (German Advisory Council on Global Change)
WEIS	Water Event Intensity Scale

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Chapter 1: Introduction

1.1 Starting Point: Problem Diagnosis & State of Current Research

With a length of about 6700 km the Nile is the world's longest river, fed by two main tributaries from the equatorial lakes region (White Nile) and the Ethiopian highlands (Blue Nile), and flowing to the Mediterranean Sea (Sutcliffe and Parks 1999). Its basin encompasses 10% of the African continent and about 280 million people in the 10 riparian countries: Egypt, Sudan, Ethiopia, Eritrea, Uganda, Rwanda, Burundi, Kenya, Tanzania and Democratic Republic of Congo (CGIAR 2010, a map of the basin is shown in Figure 1.1). An important characteristic of the Nile is its comparatively low annual discharge[1], only about 83 km^3.

The basin faces a number of challenges: the large geographic as well as socio-economic asymmetries between the basin countries (Allan 2009), the tremendous population growth[2] and the widespread poverty, underdevelopment and food scarcity. Additionally there are environmental problems like erosion and large spatial and temporal variability of rainfall and of water flows. Finally there is the currently valid water allocation allotting 87% of the water to Egypt and Sudan (Waterbury 1979). These factors have created a state of simmering conflict[3] between upstream and downstream states which recent cooperation attempts have so far failed to overcome.

A large amount of research already exists on the Nile Basin, analyzing both the causes for the conflictive situation and attempting to develop solutions. The literature can be divided into qualitative and more quantitative papers[4]. Qualitative work includes case studies and scenario analyses, which sometimes make use of empirical data (e.g. Allan 2009, Cascão 2009, Mason 2004, Waterbury 2002, Whittington and McClelland 1992, Whittington 2004). Authors from Nile Basin countries are rare but

[1] For comparison the discharge of the Amazon (comparable length) is 5518 km^3, that of the Mississippi (comparable drainage area) is 562 km^3 (Ribbe and Ahmed 2006).
[2] A doubling of the population is expected by 2050 (World Population Prospects 2008).
[3] For the purposes of this thesis the term 'conflict' is defined following Goulden et al. (2009) (whose definition is based on Yoffe et al. 2003) as "a range of types of negative interaction that encompasses mild verbally-expressed discord and cold interstate relations to hostile military acts or declarations of war between states or their representatives and institutions" (Goulden et al. 2009:2). In the intrastate case, the same definition applies, but with respect to the state and an armed group. 'Armed conflict' is specified when necessary. Cooperation also stands for "a range of positive interactions that can take many forms" (ibid.) and is rather a "reaction to conflict or potential conflict" (Keohane 2005:54 as cited by Goulden et al. 2009) than the "absence of conflict" (ibid.).
[4] The studies cited here are only exemplary. Most of them are mentioned again in the respective chapters.

examples include Amer et al. (2005) with the companion papers, Tafesse (2001) and Tesfaye (2008). Quantitative papers can be subdivided into studies utilizing models from game theory (e.g. Waterbury and Whittington 1998, Wu and Whittington 2006), economic analysis including optimization models (e.g. Wichelns et al. 2002, 2003), hydrological models (e.g. Block et al. 2007, Kirby et al. 2010), and a type of agent-based model (Guariso and Whittington 1987).

The most recent work examines the impacts of climate change[5] on the Nile Basin. Africa is commonly cited to be the continent most vulnerable to climate change, especially with respect to future water and food security, since both water resources and agriculture will be strongly affected by climate change (Boko et al. 2007). This is also true for the Nile Basin countries. Climate change is often expected to act as a 'threat multiplier' (The CNA Corporation 2007), intensifying the existing problems mentioned above and increasing the risk of conflict. However, due to the large uncertainties, it is also possible to consider it as a facilitator of cooperation. Since the effects of climate change in the Nile Basin are already visible, and since adaptation can be most efficient if started early, it is important despite the large uncertainties in the predictions to include climate change in the assessment and planning of current projects, agreements and development efforts. Research in this area is therefore strongly needed.

Current studies on the impact of climate change are either purely scientific, focusing on predicting changes in temperature, precipitation and runoff (e.g. Elshamy et al. 2009a,b, Kim and Kaluarachchi 2009), or they examine specific vulnerabilities and adaptive capacities (examples for Egypt: Agrawala et al. 2004, Eid et al. 2006, Strzepek et al. 2001; examples for Ethiopia: Block et al. 2007, Deressa and Hassan 2008, 2009, Mideksa 2010; examples for Uganda: Bwango et al. 2000). The focus of this thesis lies on an assessment of the impact of climate change on basin-wide relations. It seeks to bridge the gap between natural science and socioeconomic research in a combined and innovative approach.

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[5] Climate change is defined as "a change in the state of the climate that can be identified (…) by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer. (…) may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use." (IPCC 2007b:943) Detailed information on the current standard of knowledge can be found in Solomon (2007). In summary it can be said that it is secure that climate change happens caused by human activity and that it will strengthen in the future, having an impact on ecosystems.

1.2 Research Goals, Hypotheses, Method of Inquiry & Structure of Work

The goal of this thesis is two-fold. On the one hand this thesis is related to the development of an agent-based simulation model of the interactions in the Nile region[6]. *As a research goal we seek to understand how humans and the environment are interacting, and how this leads to conflict or cooperation.* This thesis contributes an up-to-date analysis of the current situation in the Nile region.

In a first step to address this question, an impact graph is developed that covers the interactions between the environmental and the human dimensions. A particular focus lies on the two factors of water and land (in the sense of agricultural land), since these are the main drivers of interstate conflict and cooperation in the Nile Basin. Here, and in all other parts of this thesis, the focus lies on the interstate relations in the Nile Basin. The analysis in all respects is therefore limited to the national level, subnational factors are left out for now. The impact graph presented in Chapter 2 is analyzed empirically to prepare the input parameters for the subsequent model simulations.

In connection a detailed analysis of the historic and current situation in the Nile Basin is conducted in Chapter 3 based on existing scientific literature. A causal chain is set up to connect root causes, activities and immediate causes with the occurrence of conflict or cooperation, where conflict resolution capabilities determine the actual outcome. This chain is analyzed for three different time periods in the recent history of the Nile Basin.

On the other hand, this thesis aims to analyze the impact of climate change on the occurrence of interstate conflict or cooperation in the Nile Basin. In this respect, Chapter 4 contains a discussion of the impact of climate on the system, predictions for climate change and of the vulnerability of the Nile states. Finally, in Chapter 5 the following hypothesis is examined:

Climate change influences the causal chain on three levels (affecting root causes, activities as well as being an immediate cause) and therefore alters the conditions for conflict and cooperation.

No assumptions are made about the nature of climate change as a threat multiplier or facilitator for cooperation – rather both options are discussed. An application of the

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[6] The model is being developed in the CLISEC working group (http://clisec.zmaw.de). A paper (Link et al. 2010) on its application to the Nile Basin was presented at the conference "Climate change and security" in Trondheim, Norway, June 21-24 2010.

preliminary version of the model illustrates its use and possibilities. The thesis ends with conclusions, a brief discussion of limits of the work and an outlook on possible improvements and future developments.

1.3 Political and Scholarly Relevance of the Work

The Nile Basin states currently stand at a decisive point concerning their future relations: will a basin-wide agreement based on equitable use of the water come into being, enhancing cooperation, or will the status quo from the last 50 years continue, probably leading to intensified unilateral action and possibly also intensified or even armed conflict. This happens at a time when climate change emerges as a challenge additional to the existing ones. Its influence on the question of conflict or cooperation can only be understood through a comprehensive study synthesizing predictions for climate change, the interactions between climate, the availability of land and water, and the socio-economic dimension as well as the connection between the former and conflict or cooperation. Since such a complex approach seems to be missing in the scientific discourse until now, this thesis is an important addition to current research.

This thesis is also timely and politically relevant since actions taken now, such as the basin-wide agreement currently open for signature or technical projects developing the water resources like dams, should be designed in awareness of the possible consequences of climate change, in order to be ‘climate proof’ and therefore to avoid future conflict. This work helps to improve the understanding of possible connections between climate and the occurrence of conflict and cooperation, and therefore can be the basis for assessing optimal courses of action in the future.

1.4 Sources and Background Literature

In addition to the literature on the interstate relations in the Nile Basin itself, which has already been addressed in Section 1.1, two main bodies of literature are relevant for this thesis: the research on water as a factor in conflict and of the connection between climate change and conflict[7]. These shall be reviewed here briefly.

[7] For both the literature on environmental conflicts is also important. It cannot be reviewed here, but pioneering work in this field was done by Homer-Dixon and his group in Toronto, Baechler and

1.4.1 Literature on Water and Conflict

A connection between water and conflict seems to be obvious: water is a fundamental resource for survival and very often it is a transboundary resource[8] (either surface or groundwater), necessitating interaction between the riparians over the use of the resource. So disputes or armed conflicts over use or pollution between riparians seem feasible. Therefore, in politics, media[9] and also scientific literature the 1990s were marked by a discussion of 'wars over water' as a special type of environmental conflict (e.g. Butts 1997, Gleick 1993, Homer-Dixon 1995, Remans 1995, Toset et al. 2000). However, this is questioned by Libiszewski (1995), Wolf (1998), Swain (2001), pointing out the lack of historic evidence and the multiple options and incentives for cooperation.

The conflict potential of rivers is assessed by Frey (1993). The complexity of the relationship is pointed out by Allan and Nicol (1998), who emphasize that, while water might not cause a conflict, it can still be a factor among others in it. More research has emerged on cooperation and its benefits, with an important example being Sadoff and Grey (2002) with their classification of benefits from the river, to the river, beyond the river and reduction of costs because of the river. Allan (1998) develops the concept of 'virtual water' as a way to overcome water scarcity and avoid conflict.

Research has shifted to more empirical work mainly through the developments of the Water Conflict Chronology (Gleick 2010) and the Transboundary Freshwater Dispute Database (Wolf 2010). Gleditsch et al. (2006) use these data to perform a regression analysis, and find a connection between basin size and conflict.

Wolf (2007) shows that there are far more incidences of cooperation than conflict over water[10], leading to a shift in the literature away from the water war discourse.

Spillmann and their group in Zürich, the group around Gleditsch in Oslo and the group of Matthew in Irvine (see WBGU (2009) for an overview).

[8] In total there are 261 international river basins covering 45.3% of the world's land surface (Wolf et al. 1999).

[9] An example is the quote by the former vice-president of the World Bank Ismail Serageldin from 1995: "the wars of this century were fought over oil, the wars of the next century will be fought over water." (cited by Barnaby 2009)

[10] According to the study this is driven by factors like a strong resilience of cooperative agreements once established, some shared interests of the riparian states and economic considerations due to large costs of war.

Yoffe et al. (2003) confirm this[11] and develop a Water Event Intensity Scale which is used by Zeitoun and Warner (2006) for their more complex Conflict Intensity Frame. While both are rating systems on a continuum between conflict and cooperation, the latest advancement is the recognition of the parallel occurrence of conflict and cooperation and the framing of both as interacting visualized in form of a matrix (Zeitoun and Mirumachi 2008). These rating systems are shown in Appendix B.

1.4.2 Literature on Climate Change and Conflict

This field is relatively new and the debate about possible links between climate change and conflict is just beginning, hampered by large uncertainties in both areas. The main causal chains which are discussed link sea level rise, increasing water and food scarcity and the impact of storms and floods with migration[12] and increased competition over resources. The latter arises from weakened state capacity that leads to local conflict through grievances and new rebel opportunities. Since 2007 an increasing securitization of climate change can be observed in media, politics and think tanks (e.g. the special debate of the UN Security Council on the topic on April 17 2007, UNSC 2007), which is investigated in scientific studies (e.g. Brauch 2009, Brzoska 2009, Petri 2010). The study of the German Advisory Council on Global Change speaks of a 'new quality of conflicts' (WBGU 2009:162), elsewhere climate change is called a 'threat multiplier' (e.g. The CNA Corporation 2007).

While such argumentation is also found in research literature (Brown et al. 2007, Lee 2009, Maas and Tänzler 2009, Swart 1996), so far not much hard evidence has been found. Skepticism of a potentially oversimplified connection has risen, and the need for more empirical studies is being emphasized (e.g. Barnett 2003, Barnett and Adger 2007, Dabelko 2009, Hulme 2007, Nordås and Gleditsch 2007, Raleigh and Urdal 2007, Salehyan 2008, Scheffran 2008). Studies on the connection between rainfall and armed conflict (e.g. Hendrix and Glaser 2007, Jensen and Gleditsch 2009, Miguel et al. 2004) as well as temperature and armed conflict (e.g. Buhaug 2010, Burke et al. 2009, Zhang et al. 2007) find rather ambiguous evidence for a link[13].

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[11] They find 67% of cooperative events compared to only 28% conflictive events for 122 international river basins in the International Water Events Database (Wolf 2010) for the time between 1948 and 1999.

[12] Migration as a factor will not be considered at all in this thesis, since it would be a subject on its own. Environmental migration is so far not well investigated scientifically and the link to conflict is not established. It is also more likely to be an internal rather than an interstate factor.

[13] Interestingly, at the conference "Climate Change and Security" in Trondheim, Norway 2010, Marshall Burke showed that when he extends his analysis of temperature and conflict conducted in Burke

In summary, a connection between climate and interstate war is not supported by current research. Now, a greater focus is placed on indirect links and small-scale, internal conflicts (e.g. Hendrix and Salehyan 2010, Smith and Vivekananda 2007) as well as more complex approaches like the one presented in this thesis. Many open questions remain.

1.5 Theories and Methods

This section provides the theoretical and methodological background for the work presented in this thesis. The analysis of the water conflict in the Nile Basin is conducted in the framework of the theory of hydro-hegemony, which is described below. It is followed by a brief overview of the modeling approach used in a larger project, which is the framework for this thesis. Finally the data availability and quality of the data used in the empirical analysis of the impact graph are discussed.

1.5.1 The Theory of Hydro-Hegemony

The hydro-hegemony theory was conceptualized by Zeitoun and Warner (2006) as an analysis tool for transboundary water conflicts. It combines the concepts of hegemony, power and intensity of conflict into one framework.

Hegemony is defined as "leadership buttressed by authority" (ibid. p438) and the hegemon can use different mechanisms to achieve compliance (coercive, utilitarian, normative and ideological mechanisms). The hegemon can be positive, providing leadership, order and stability (and these positive effects outweigh the negative ones), or negative, more dominant, with large asymmetries between the hegemon and the co-riparians.

The dimensions of power relevant to transboundary water conflicts and considered by Zeitoun and Warner (2006) are hard power (military, economic, political support and also geographical features like riparian position), bargaining power (the power to set the agenda and stall or advance activities) and ideational power (best described by Strange (1994) as "the strong implant their ideas, even their self-serving ideology, in the minds of the weak, so that the weak come to sincerely believe that the value-

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et al. (2009) from 1981-2002 with new conflict data from 2002-2008, the significance of the correlation decreases strongly.

judgments of the strong really are the universally right and true ones" (p176, cited by Zeitoun and Warner 2006)).

The intensity of conflict is included to emphasize that "the absence of war does not mean the absence of conflict" (Zeitoun and Warner 2006:441). A 'Conflict Intensity Frame' is developed, trying to combine several viewpoints on conflict intensity like the NATO scale (NATO 1999) and the Water event intensity scale (WEIS, Yoffe 2001). A further development of this analysis is the shift away from the continuum (war vs. cooperation) to a parallel, interacting occurrence of the two. This is done using the TWINS matrix (Transboundary Waters Interaction Nexus, Mirumachi 2006) of conflict and cooperation presented in Zeitoun and Mirumachi (2008). Both the WEIS scale and the TWINS matrix are described in more detail in Appendix B.

Finally, hydro-hegemony rests on three columns: riparian position, power (with its three dimensions) and exploitation potential. Power is found to be the prime determinant, at least in examples from the MENA region. The degree of hydro-hegemony can be measured in these three categories. The control the hydro-hegemon has rests on its coercive resources (international support, financial mobilization and riparian position). He can employ different strategies (resource capture, containment or integration) based on his tactics (military force, active stalling, covert actions, treaties, incentives, securitization etc.). The co-riparians have the option of counter-hegemonic strategies, mainly by using bargaining power. This leads to a continuum of interactions between a positive hydro-hegemony (cooperation, shared control), a negative or positive hydro-hegemony (stifled competition, consolidated control) and contested hydro-hegemony (competition, contested control).

The advantage of this theory is the rather simple analytical tool it provides to analyze transboundary interactions. It seems to lack a sound inclusion of international law (though at the moment there actually is not much applicable international law)[14].

This theory was chosen because it provides an encompassing, well designed and clearly defined framework to analyze transboundary river conflicts, combining several other theories. Also, the agent-based modeling approach can be connected well to this theoretical analysis. Another option would have been a game theory approach. However, this already exists in the literature and does not combine well with the si-

[14] The main agreement is the UN Convention on the Law of Non-Navigational Uses of International Watercourses from 1997, based on the Helsinki Rules on the Uses of the Waters of International Rivers from 1964. It so far has not been ratified. The Berlin Rules on Water Resources superseded the Helsinki Rules in 2004 and are a summary of customary international law applied to freshwater resources. Important principles are "equitable use", "no significant harm" and "prior notification".

mulation model. Other approaches like negotiation theory emphasize specific aspects of the interstate interactions and are therefore not so well suited to the goal of this thesis, which is to connect environmental and human aspects.

1.5.2 The Agent-Based Modeling Approach

This thesis is related to a larger project to develop and apply an agent-based simulation model of interactions in the Nile region. Such a model is new not only in the scientific literature on the Nile but also in the literature on the climate change-conflict nexus. Agent-based models are increasingly common in other areas of social sciences such as economics, demography, geography or transportation (see Billari et al. 2006, Bossel 2004, Ford 2009 for overviews). The goal of this modeling exercise is to analyze the Nile region as a dynamical system, in which the agents are the states and the simulation is based on their behavioral patterns. Interactions are coded in mathematical functions and equations that change from one time period to the next. In the future, it will also be used as an optimization model. The model of the Nile river conflict used here is described in detail in Link et al. (2010), while the fundamental principles are outlined in Scheffran and Hannon (2007), Scheffran (2010), Scheffran et al. (2010). While it currently is used to simulate interstate relations, it may also be applied to intrastate conflicts later on.

The advantage of the modeling approach is the possibility to analyze complex, dynamic interactions and the ability to explore different strategies for the actors with the possibility to identify promising paths of action. Disadvantages include a necessary simplification in comparison to reality and the uncertainties in the assumptions and data, which enter the model. It is important to keep in mind the limitations and the inability to draw simple predictions from such a model. Of course, it is also impossible to prove the correctness of the model, so extensive tests are necessary within the framework the model is supposed to be applied in.

1.5.3 The Empirical Impact Graph Study

An impact graph is the first step in the development of a model. It explores the structure of the system and the possible interactions between climate, environment and socio-economics, and on this basis the possibility of conflict or cooperation can be deduced. It is empirically analyzed, collecting relevant data from various publicly available databases as listed under *Databases* in the Bibliography. These databases

were chosen for their extensive data collection, their good reputation and the easy access.
Since the data is compiled not only through studies and surveys conducted by the respective institutions, but also from governments, NGOs and other sources, inconsistency is one problem. However, for these extensive databases, measures exist to tackle this issue so that the highest possible degree of reliability is ensured. The following discussion of weaknesses of data is largely based on quality assessments provided by the respective agencies hosting the databases[15].
The availability and quality of data varies depending on the quantity being considered. Data related to water are especially problematic, since they tend to be of lower quality and/or incomplete, either because the data was not collected or access is restricted[16]. Data on land use or irrigation is often based on estimation rather than actual measurements. Economic data like the Gross Domestic Product (GDP) suffer from the problem of how to measure services or technical improvements, but also from large informal sectors that are common in developing countries and difficult to include. Composite indices like the Human Development Index (HDI) or the Composite Index of National Capabilities (CINC) are not easy to assess in their uncertainties, since they combine the uncertainties of a number of other quantities, and especially the weighting of these is not necessarily straightforward. Population data depend on a system of civil registration, which is often unreliable in developing countries, so surveys are employed which introduce a larger degree of uncertainty.
The data on governance (Worldwide Governance Indicators) used here deserve special positive mention, since they are published together with error margins. These highlight specifically the possible insignificance in pair-wise or time-based comparisons, if these margins overlap (Kaufmann et al. 2009).
When looking at a time series of data, problems include gaps in the data, possible changes in collection methods or changes in access to data. Therefore changes in data from one year to the next might reflect methodological changes rather than an actual change in the quantity measured. This makes long term trends important. Also, during times of war often no reliable data can be collected, at least in certain areas of

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[15] In addition to the quality also the significance of a certain quantity is not always obvious. The number of roads does not indicate anything about their quality, and a high level of education does not mean there are jobs available. This needs to be kept in mind when drawing conclusions from empirical data.
[16] This particularly affects data of the Nile flow, which is generally treated as a matter of national security and can be found publicly only until the 1980s (Declan Conway, private communication).

a country. The independence of Eritrea from Ethiopia in 1991 introduces another uncertainty, since often it is not clear how this is included in the measurements.

Since different countries are compared in the thesis, it should be mentioned that such comparisons also can suffer from a number of problems. One example is different definitions of the data collected by the various countries, another is differences in measurement techniques. Also, not all data are available for all countries for the same years from the same sources.

These data limitations have been covered in such detail since they should be kept in mind when discussing data. However, for the purpose of this thesis the data availability and quality are adequate with respect to country-level data. Both for the time series and interstate comparisons shown here the data for the chosen countries are sufficient and satisfactory to draw conclusions on their relative economic, environmental, political and developmental status as done in the following chapters. The high difficulty to obtain reliable subnational data was part of the reason to focus on the interstate rather than the intrastate level.

Chapter 2: The Impact Graph of Interactions in the Nile System: Connections between the Environmental and Human Dimensions

The goal of this chapter is to analyze the Nile Basin systematically in terms of the interactions between the environmental and the human dimension as shown in the impact graph in Figure 2.1. The analysis is substantiated by data for the indicators chosen for every box of the graph. An overview of these indicators is given in Appendix C. First the mutual connection between the given environmental conditions and human use and activity is discussed. Within the human dimension interactions in the socio-economic framework play a role, including political, economic and developmental factors which in combination affect human wellbeing.

The countries of the Nile Basin can be separated in three groups: (1) the downstream countries Egypt and Sudan, in whose territory almost no contribution to the Nile waters originates but who largely depend on the external Nile flow; (2) Ethiopia as the country of origin of the Blue Nile which contributes 85% to the total downstream flow; and (3) the countries in the south of the basin – Uganda, Tanzania, Kenya, Rwanda, Burundi[17] - countries of origin for the White Nile which stress their joined interest through the East African Community (EAC)[18]. As a representative of the EAC states only Uganda will be included in the discussion. This is justifiable since currently the White Nile only contributes 15% of the downstream flow[19] (and even less in the months of high flood) and therefore the main tensions are between the downstream states and Ethiopia. Also, the EAC countries have agreed to act as a bloc in negotiations with the other basin states (Kagwanja 2007).

2.1 Human-Environment Interactions

The environmental characteristics of the Nile Basin vary tremendously between countries[20]. While the climatic conditions are discussed in Chapter 4, these subsections focus on the resulting availability of water and land (where the latter means land suited for agriculture) and the human use of these resources in the countries. Population growth, due to its important effect on use, is also discussed in this section.

2.1.1 The Availability of Water[21]

Uganda has total renewable water resources of 66 km^3/yr, 41% of which are external. Nile outflow is 37 km^3/yr. Ethiopia is sometimes called the "water tower of Eastern Africa" (Swain 1997), because of its high rainfall giving rise to 14 major rivers flowing from its high elevations to neighboring countries[22]. This leads to high renewable water resources of 122 km^3/yr, but also puts Ethiopia in a difficult position since 80% of its water resources are transboundary.

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[17] While Eritrea and the Democratic Republic of Congo are also nominally part of the Nile Basin, their respective area in the basin as well as water contributed is negligible and they will therefore be excluded here.

[18] The East African Community was founded originally in 1967 by Kenya, Uganda and Tanzania, collapsed in 1977 and was revived in 2000. It is mainly focused on common economic goals like a customs union, but also serves as a framework to address water issues, especially with respect to Lake Victoria. Rwanda and Burundi joined in 2007 (EAC 2010, Kagwanja 2007). Tensions within the EAC over the use of Lake Victoria cannot be covered within the framework of this thesis.

[19] The reason for this is the evaporation of large amounts of water in the Sudd, an extended swamp area in southern Sudan. Plans to reduce evaporation and therefore increase the amount of available water through draining and bypassing it with the Jonglei canal were interrupted by the Sudanese civil war in 1984. While the project, which would strongly increase the importance of the White Nile for Egypt and Sudan, has resurfaced after the Sudan Peace Agreement in 2005 (Ahmad 2008), the referendum on the independence of South Sudan in 2011 and the unclear expectations for the situation afterwards are currently preventing any progress.

[20] Variations are also large within countries, however this is not the focus of this thesis.

[21] In this subsection, all data are taken from Aquastat (2010), unless indicated otherwise.

[22] This high rainfall is limited to the western and central parts of the country, while an arch from the northeast via east to southeast is rather dry.

Sudan produces only 30 km^3/yr of renewable water internally, while 119 km^3/yr enter the country from Uganda and Ethiopia (dependence ratio of 80%). Due to evaporation in the wetlands (which strongly reduces the possible use of the White Nile, indicated by "Sudd" in the impact diagram) and the 1959 agreement[23] with Egypt the total natural renewable water resources of 149 km^3/yr are reduced to 64.5 km^3/yr actual renewable water resources.

Egypt's dependence ratio on external water is with 99% even higher. Due to the low rainfall, barely any renewable water is produced internally. From the natural Nile inflow of 84 km^3/yr from Sudan it has secured 55.5 km^3/yr in the 1959 agreement, renewable groundwater makes up another 1.3 km^3/yr[24]. While the other three countries have a considerable amount of soil water consumption (Ethiopia: 31 km^3/yr, Sudan: 50 km^3/yr, Uganda> 45.5 km^3/yr, Allan 2009), Egypt has none. It produces some additional water using desalination and wastewater treatment, but the percentage is still very small.

From these numbers it becomes clear, that Egypt and to some lesser degree Sudan are strongly dependent on water from the upstream countries, and therefore are directly affected by rainfall in the headwater regions of the Nile. This is also illustrated in Figure 3.1 (environmental dimension).

2.1.2 The Availability of Land

In terms of land availability three factors have to be considered – the geography, the availability of arable land and land degradation and erosion.

Geographically, the basin consists largely of low lands. The highest regions with over 3000 m are the highlands of Ethiopia and the area around Lake Victoria. There are mostly grasslands, savannas and in Ethiopia also forests. The countries with the highest percentage of desert in the Nile region are Sudan and Egypt. About 96% of Egypt's land area is covered by deserts, confining the population and agriculture to a small fraction of the land along the Nile and the coast and leading to large pressure on the environment[25] (Ibrahim and Ibrahim 2006).

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[23] See Appendix D for an overview of relevant agreements.

[24] 1 km^3/yr of this also enters from Sudan.

[25] Large desert reclamation projects, notably in northern Sinai and in the Toshka region in the south of Egypt attempt to open up new areas for settlements and agriculture. However, they require large amounts of water to be diverted out of the Nile, are very costly and the economic viability is unclear (Lonergan and Wolf 2001).

The available arable land differs strongly between the countries of the basin. It is shown in Figure 3.1 (environmental dimension) as a percentage of total land area. While this percentage is highest for Uganda, Uganda is also the smallest of the countries. In terms of total potential arable area (potential for irrigated as well as rainfed agriculture)[26], Sudan leads by far with almost 90 Mio ha[27]. Ethiopia has about 45 Mio ha, Uganda 14 Mio ha and Egypt only 4.5 Mio ha[28].

Finally, erosion is a large threat, mainly in Ethiopia (water erosion due to the steep terrain in the highlands) and in Sudan (wind erosion, desertification). Upstream erosion originally had a positive effect on downstream land availability through the deposition of nutrient-rich sediments, leading to the high fertility of the Egyptian Nile valley and protecting the Nile delta region from erosion by the sea. Anthropogenic changes to the system in the form of dams, especially the Aswan High Dam, have changed this. Sediments no longer reach Egypt, but are deposited behind the dams. This leads to increased riverbed and delta erosion in Egypt as well as to the increasing need for artificial fertilizers. It also causes siltation of dam reservoirs and a decrease of water storage capacity, thus impacting directly water availability. Sudan's dams are especially affected by this since the rivers from Ethiopia, where erosion is high, carry large amounts of sediments (Waterbury 2002).

2.1.3 Use of Land and Water and Feedback Effects

The availability of land and water shape the opportunities for use, but use also has feedback effects on the resource availability. Use covers the dimensions of industrial, agricultural and human use.

Figure 2.2 shows uses of water and land. As can be seen from the figure, while Egypt is currently using almost all of its actual available renewable water[29], and Sudan still more than half, Ethiopia and Uganda have negligible withdrawals. This reflects the higher water availability, larger fraction of rainfed agriculture, but also an underdeveloped water resource management sector upstream. It also shows that Egypt has

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[26] The estimations of potentials for agriculture, irrigation or hydro-electric power (HEP) are taken from literature and their reliability cannot be assessed.

[27] Sudan is therefore also called the potential "bread basket of Africa" (Zakieldeen 2009), but is far from fulfilling this potential.

[28] Data for irrigation potential from Aquastat (2010), for rainfed potential from Terrastat (2010).

[29] Here, "actual available water" means water secured under a treaty, in this case the 1959 agreement between Egypt and Sudan, which allocates water shares to both parties.

little opportunity to accommodate increased demand without changes to supply and/or the demand structure.

Currently, as shown in the figure, in all 4 countries except Uganda (where it ties with municipal withdrawal), agriculture accounts for the largest use of water[30], reflecting the important role agriculture plays in the societies. The figure also shows that Egyptian agriculture is based almost completely on irrigation (accounting for the large withdrawals), while all other countries have large unused potential both for rainfed and irrigated agriculture. The only country with a noteworthy industrial water withdrawal is Uganda (17%), for the other countries it is 6% (Egypt), 1 % (Sudan) and only 0.4% (Ethiopia). Municipal withdrawals are somewhat larger (Egypt: 8%, Ethiopia: 4%, Sudan: 3%), especially in Uganda with 43% (Aquastat 2010, data from 2000 and 2002)[31].

2.1.4 The Reverse Feedback from Use to Resource Availability

As the arrows in Figure 2.1 show, the interaction between use and land/water availability goes both ways. Land use leads to pollution. Water is affected by agricultural pollution (pollution from fertilizers and pesticides, salinisation from irrigation and pollution from herbicides used against submerged weeds and water hyacinths in canals and drains), municipal pollution (untreated sewage) and industrial pollution. This is mainly a problem in urban areas. Egypt is by far the largest user of fertilizers, as well as the country with the largest industrial output of the Nile countries (illustrated in Figure 2.3, data from 2006). It therefore also causes the largest pollution. While upstream pollution carried into downstream countries could definitely be a possible threat to downstream water availability in the future, currently this is a small concern. At present the region most significantly affected by pollution, originating mainly in the Cairo area, is the Nile delta (Mason 2004).

Land availability in the Nile region is mainly impacted by human-induced degradation. In Egypt this is largely chemical deterioration from agricultural use, while in the other countries it is mainly water erosion caused by overgrazing and deforestation. In Uganda and Ethiopia the area affected is largest, with 62% and 31% of the total land area respectively. However, while the area affected in Egypt is small (8% of the total

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[30] Water use in this context always means gross use, since there is no data available for reusing water. This is done, for example in Egyptian irrigation systems, but not to a very large degree.

[31] Unfortunately no information could be found on why the withdrawal pattern is so different for Uganda.

land area), Egypt has few options to relocate agriculture to other areas and depends on the soils along the Nile (FAO 2000). Another problem is deforestation due to a large demand for wood as fuel, especially in Ethiopia and Sudan, which in turn increases erosion (Hamouda et al 2008).

2.1.5 Use of Land and Water and Population Growth

Population growth has a large effect on the use of resources, and it is high in all Nile countries. By 2050 increases by factors of 1.5 (Egypt), 2 (Ethiopia), 1.8 (Sudan) and 2.7 (Uganda) are expected (World Population Prospects 2008, see Figure 2.4). According to the Falkenmark water stress index (Falkenmark 1989), which measures hydrological water scarcity as available water per capita[32], currently Egypt can be classified as water scarce (678 m^3/capita in 2010), Sudan and Ethiopia as water stressed (1436 and 1493 m^3/capita in 2010 respectively) and only Uganda has relative water sufficiency (1953 m^3/capita in 2010) (Aquastat 2010, World Population Prospects 2008). Figure 2.5 shows that, for equal amounts of available water, increasing population will lead to a state of water scarcity for Sudan, Uganda and Ethiopia by 2030, while Egypt will become severely water scarce[33].

The larger population also strongly exacerbates land degradation and leads to more urbanization, since the resources in rural areas cannot accommodate people anymore. Finally, food security becomes increasingly difficult to achieve unless development enables a more productive agriculture, more employment in other sectors and greater revenues to import food from other countries.

2.1.6 Use of Land and Water and Human Wellbeing

Use is interrelated with human wellbeing, mainly in terms of water available for human use. The availability of water for consumption and sanitation is a basic necessity and considered to be a human right[34]. Clearly, increasing water scarcity due to popu-

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[32] Classification: water stressed: < 1700 m^3/capita/yr, water scarce: < 1000 m^3/capita/yr, severely water scarce: < 500 m^3/capita/yr

[33] Note that these classifications are again average value over the whole country. Especially for Ethiopia and Uganda, regional differences are high and while water scarcity can be severe in some regions or in some years, other regions are water sufficient and also in the future there will be areas with sufficient water.

[34] This “right to water” is inferred from Article 11(1) of the International Covenant on Economic, Social and Cultural Rights (in force since 1976, all Nile Basin states are parties), which states “the right of everyone to an adequate standard of living …, including adequate food, clothing and housing” (ICESRC 1966, see also UN Committee on Economic, Social and Cultural Rights 2003).

lation growth as discussed in the previous section negatively impacts human wellbeing.

Access to sanitation is one of the large challenges in developing countries and also in the Nile Basin, since the lack of sanitation leads to diseases and causes pollution of water resources. In 2004, 70% of Egypt's population had access to an improved source of sanitation, but only 43% in Uganda, 34 % in Sudan and even 13% in Ethiopia (EarthTrends 2010). The treatment of wastewater is negligible or no data are available (Aquastat 2010).

Increased human wellbeing is accompanied by increased development and higher standards of living, which typically leads to higher water consumption. This can be illustrated by the concept of the water footprint, which includes the water consumption volume, consumption patterns, climatic conditions and agricultural practices of a country. In the report on national water footprints, Chapagain and Hoekstra (2004) show that the water footprint both from domestic as well as industrial consumption is clearly positively correlated with the per capita gross national income of a country[35]. Based on these correlations an increase in water use with development would be expected for the Nile countries, since development would entail first more irrigation, and even if a shift occurs away from agriculture, industrial and household use of water would increase as well[36].

Finally, use of water for irrigation has an impact on wellbeing through health. For irrigation water has to be stored behind dams (large dams like Aswan, but also microdams as discussed for Ethiopia – see Waterbury and Whittington 1998) and channeled through small canals. Standing or slowly moving water gives rise to water-born diseases like bilharziosis, and increased infection rates have been found in relation to dam and irrigation projects (see for example Stephenson 1947).

2.1.7 The Transboundary Relevance of Water Use

In the concept of hydro-hegemony the riparian position is one category enabling hegemony. In principle an upstream position is favorable because the use of water in upstream states has an impact on water availability in downstream states through two

[35] Such a correlation is not visible for the water footprint for agricultural consumption, since here lower developed countries often depend strongly on the agricultural sector and at the same time have to employ large-scale irrigation to enable farming due to climatic conditions. Sudan is such an example, with a high overall water footprint mainly due to large agricultural consumption, despite its low development.

[36] Increased efforts in conservation or efficiency increases can offset this somewhat.

linkages – when water is taken out of the system (for example for irrigation), or through pollution. On the other hand, using water for the production of hydroelectric power still allows for it to reach the downstream states and therefore does not impact their flow rates. This connection between use and availability is also shown in Figure 2.1. The impact of use in the equatorial states on Sudan and Egypt is damped by the large evaporation in the Sudd swamps, leaving only little White Nile water to be used downstream. This is indicated by the box "Sudd" in the impact diagram, influencing the strength of the impact arrow. The conflictive potential arising from this connection will be discussed in Chapter 3.

The "use"-factor is the bridge connecting the environment and the socio-economic dimension, which will be described in the following section.

2.2 The Socio-Economic Dimension

The dimensions of resource use, production and human wellbeing are not only affected by environmental conditions, but also by socio-economic factors. This part of the impact graph consists of the following factors: political situation, labor productivity, production and human wellbeing. These will be discussed in this section.

2.2.1 Political Situation

One important factor for use of resources and labor productivity is the political situation in a country with respect to the involvement in armed conflicts and the quality of governance, since these factors provide the framework for economic activity.

Intra- as well as interstate armed conflicts bind financial as well as human resources. During such conflicts, the demand for efficient water resource management is also lower, since there is no capacity for industrial or even high level agricultural development which would require significant quantities of water[37]. Currently Uganda (armed conflict with the Lord's Resistance Army rebels), Sudan (Darfur, South Sudan, conflict over government) and Ethiopia (armed conflict over Ogaden region and with the Oromo ethnic group) are involved in minor armed conflicts and have been

[37] Actually the link could be seen in both directions here, since economic collapse could lead people to join for example rebel movements to make a living or to protest neglect, as in Darfur.
An example is Uganda. During the civil war in the 1980s, the agricultural sector largely collapsed and mainly subsistence farming survived, which is less efficient and less able to make use of large amounts of water (Byrnes 1991).

more or less consistently involved in armed conflict since 1979, while Egypt has not experienced armed conflict since 1980 (Uppsala Conflict Data Program 2010[38]).

Governance can be assessed using the Worldwide Governance Indicators, consisting of voice & accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption (Kaufmann et al. 2009)[39]. Looking at Table 2.1 clearly Sudan is far behind in all of these categories. Because of overlapping error margins it is harder to draw significant comparisons between the other states, though Uganda is significantly leading in voice & accountability and both Uganda and Egypt fair best in regulatory quality. Still, all scores are fairly low, barely reaching the 50th percentile in some cases, indicating the need for improvement as an important factor to achieve development.

2.2.2 Labor Productivity

The factor of labor productivity depends both on the size of the labor force as well as the qualification of workers. The size is mainly influenced by population growth. This constitutes a problem faced by all states in the region - populations are growing which results in a high fraction of young people in need of employment. The fraction of population aged 0-14 is between 32.5% in Egypt and 49% in Uganda (World Development Indicators 2010, data for the year 2008). Unemployment rates among young men (aged 15-24) are 23.3% (2005) in Egypt and 19.5% (2006) in Ethiopia, while it is even worse for young women with 62.2% (2005) in Egypt and 29.4% (2006) in Ethiopia (World Development Indicators 2010). For Uganda, no data could be found, while for Sudan, only the total unemployment rate of 18.7% (The World Factbook 2010, data for the year 2002) is available.

The impact of the political situation on the labor category is, on the one hand, related to the occurrence of armed conflict and need for military personnel, reducing the size of the workforce. On the other hand the political situation directly influences the capacity of the state to improve labor productivity by improving education and infrastructure, and by providing incentives for innovation and investment, thereby increasing the degree of development. Table 2.2 shows data as indicators for education (literacy rate and secondary education enrolment) and infrastructure (total road net-

[38] In this study a war is defined as having more than 1000 battle related deaths in a year, while a minor conflict has between 25 and 1000 battle related deaths in a year. Here, only wars and minor conflicts are included. The categories of one-sided and non-state violence are left out since these data only go back to 2002 and are therefore difficult to use in the long-term analysis done in Chapter 3.

[39] These perception-based indicators are defined in Table 2.1.

work and vehicles per 1000 people – the land area is shown for perspective). Based on these data, a higher productivity would be expected for Egypt due to its leading role in most categories[40].

2.2.3 Production

Labor productivity together with the use of resources shapes the economy of the country, labeled here as "production". As is illustrated in Figure 2.6, agriculture is the dominating sector in Ethiopia, Sudan and Uganda, and also plays a large role in Egypt. In the former countries it accounts for over 70% of employment, and in Egypt still for 40% (EarthTrends 2010). It is also an important source of foreign income (Lele 1989), but its contribution to GDP is below 50% in all countries (though close in Sudan and Ethiopia). The disparity between agricultural labor and contribution to GDP is particularly large for Uganda[41]. It reflects the importance of subsistence farming and a related low level of inefficiency in agricultural production, but the steady decline of the agricultural sector also reflects growth in the other sectors and of the GDP in general (FAO 1998).

Industry provides less contribution to GDP and less labor force than services. In Ethiopia and Uganda the industrial sector is largely related to food processing. This also plays a role in Egypt, but Egypt has important textile and tourism sectors as well, while in Sudan oil, cotton grinning and textiles play a major role. In relation to resource use it is evident from Figure 2.2 that agriculture accounts for most of the water consumption in Egypt, Sudan and Ethiopia.

2.2.4 Human Wellbeing

The final factor in the socio-economic dimension of the impact diagram is human wellbeing, which is directly affected by production, resource use (which has been discussed above already) and the political situation. Human wellbeing is a multi-dimensional concept, including material, physical, social, psychological and ecological facets (Alkire 2002). The linkage from production exists on an individual level (the ability on a material level to achieve a certain standard of living), but also on a

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[40] While the road network in Uganda is comparatively large for the size of the country, it has to be taken into account that the population in Egypt is concentrated in a very small percentage of the total land area along the coasts and the Nile.

[41] In Uganda, the service sector accounts for 52% of the GDP and for most of the wage labour with high literacy (Blake et al. 2001).

community and state level (an economy which enables the state to provide services like health, security and education).

One rather traditional, common method of measuring human wellbeing is the Human Development Index (HDI) (Human Development Report 2009)[42]. In terms of the HDI, Egypt (HDI=0.703, rank=123, Human Development Report 2009, data for 2007), Sudan (HDI=0.531, rank=150) and Uganda (HDI=0.514, rank=157) are medium-developed countries, while Ethiopia (HDI=0.414, rank=171) belongs to the states with low development.

If human wellbeing is defined to include also a political dimension, related for example to personal freedom, participation and freedom of press, it is directly influenced by the political situation as well. It also in turn can have an influence on the political situation, for example if high levels of inequality in the society lead to unrest[43]. Finally, human wellbeing also influences population growth, since typically higher developed countries are characterized by declining birth rates.

2.3 Conclusion

This concludes the analysis of the impact graph, leaving only "external factors" which will be relevant in the discussion on interstate relations in the following chapter. The complex interactions and interdependencies in the Nile Basin were separated into the connections between the human use and the environmental dimension and the connection of use with the socio-economic situation. The focus was on the four countries with the most conflictive as well as cooperative potential: Egypt, Sudan, Ethiopia and Uganda as representative of the equatorial states. The connection to conflict and cooperation will be covered in the following chapter.

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[42] For a general discussion of composite indices measuring human wellbeing including other options than the HDI see McGillivray and Noorbakhsh (2004).
The HDI includes the dimensions of health measured by life expectancy at birth, education measured by combining the adult literacy rate and the gross enrolment ratio (for primary, secondary and tertiary schools), and the standard of living measured using the GDP/capita. It is calculated to range from 0 to 1. Countries are classified as very highly developed (HDI≥0.9), highly developed (0.8≤HDI<0.9), medium developed (0.5≤HDI<0.8) and lowly developed (HDI<0.5).

[43] A large body of research exists investigating this connection, a discussion of which is beyond the scope of this thesis.

Chapter 3: Conflict and Cooperation in the Nile Basin

This chapter looks at the occurrence of conflict and cooperation in the Nile Basin by first comparing the states based on factors from the analysis in the previous chapter. This is the historic status quo, and it is analyzed in the framework of hydro-hegemony theory as outlined in Section 1.5.1. Then the changes in the past two decades are discussed and the analysis is summarized in the framework of a causal chain.

3.1 Interstate comparison: Asymmetries in the Nile Basin and a Hydro-Hegemon

Based on the different interacting dimensions described in the previous sections, and following Allan (2009), four main areas of comparison between the basin states are defined: environment, development, political and economic power. Figure 3.1 shows this comparison for selected proxy indicators as described in the figure caption. For the first two dimensions the indicators were chosen with respect to the main factors of this analysis: land and water, and, related to those, food and electricity. Political power includes both military power, represented by the Composite Index of National Capabilities (Correlates of War 2010), as well as the capability to provide services, represented by an indicator for government effectiveness (Worldwide Governance Indicators 2010). Economic power consists both of own economic ability (GDP) and foreign direct investment.

Clearly in all dimensions a large asymmetry can be seen. It is in favor of the upstream countries in the environmental dimension, together with their riparian position. Egypt however dominates in the economic, political and developmental dimension. In terms of the determinants of hydro-hegemony, Egypt therefore dominates in the category of hard power, also enabling a large exploitation potential, which is visible in its extensive use of water for irrigation and the construction of the Aswan High Dam.

Egypt has also enjoyed extensive external support[44], during the colonial era from the colonial power Great Britain (enabling the 1929 agreement) and during the cold war from its allies (first the Soviet Union, enabling the construction of the Aswan High

[44] This support is mainly due to its strategic position and especially the Suez Canal (Waterbury 2002).

Dam, and after 1971[45] the USA). With the agreements of 1929 and 1959[46] 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).

These historical successes have enabled Egyptian dominance also in terms of soft, specifically bargaining power. It bases its position on the principles of 'historic rights' and 'avoid significant harm', which are part of international water law, and has managed to make this the defining factor of the basin discourse until the 1990s (Cascão 2009). It 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)[47]. This, as well as the support mentioned above, is symbolized by the "external factors" in the impact graph. Egypt has been aided by the long-term weakness of the upstream states, caused by armed conflicts, political instability and low development (Cascão 2009). Some argue that Egypt has even furthered this weakness, for example by undermining governments (e.g. in Sudan before 1959, Zeitoun and Mirumachi 2008). It therefore has managed to be in "control of the rules of the game" (Zeitoun and 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 focus away from the needs of the upstream states (Cascão 2009). Those were not able to practically challenge this, despite many formal statements especially by the Ethiopian government reiterating its right to use and develop the waters of the Nile[48].

In the framework of hydro-hegemony theory Egypt therefore enjoys historical domination in 2 out of 3 dimensions: power (in all its aspects), the most important determinant (Zeitoun and Warner 2006), and exploitation potential. With these it managed successfully to more than outweigh its disadvantage stemming from its downstream position. It can therefore clearly be categorized as the hydro-hegemon of the Nile

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[45] In the 1970s the alliances in the Nile Basin changed. Egypt aligned itself with the USA after the death of President Nasser. Ethiopia, under a new communist regime, switched to the SU block (Waterbury 2002).

[46] See Appendix D for an overview of relevant agreements.

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

[48] 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" (quoted by Collins 1990).

Basin. Its control of 75% of the Nile water and its success in preventing water development in the upstream states makes it a dominant hydro-hegemon. This influence on the upstream states is symbolized by the arrows connecting Egypt with the upstream states in the impact diagram.

3.2 Shift to a Contested Hydro-Hegemony

3.2.1 Relative Changes in the Dimensions of Hydro-Hegemony

In the past two decades, Egypt's hegemony in the 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 increasing population pressure as discussed in Section 2.1.5, increasing demand for water and food and therefore the upstream desire to develop the irrigation potential. When population growth enhances water stress, development is imperative, since a higher degree of development increases the ability to cope with the problem. This is visualized in Figure 3.2. It 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[49]. While Egypt, as a highly developed state, can remedy its large level of hydrological water scarcity, Ethiopia suffers from increased stress levels when looking at the social water scarcity index. This is exacerbated by population growth. Finally, increasing development enhances the need for energy, further enhancing the need to develop the large HEP potential.

The increased capacity is mainly due to improvements in the economic sector. This can be seen in Figure 3.3: all upstream states have seen large levels of economic growth since the mid-1980s, even surpassing that of Egypt. Ethiopia, despite its non-oil economy, 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 as shown in Figures 3.4 and 3.5. Sudan especially attracts more foreign investment, probably due to the exploitation of its oil, while investment is somewhat erratic in Ethiopia and still substantially lower in the upstream states than in Egypt. Ethiopia leads in development assistance, while this decreased noticeably for Egypt since the

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[49] The Social Water Scarcity Index is calculated from the Hydrological Water Scarcity Index (defined as hundreds of people sharing 1 Mio 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).

beginning of the 1990s. The accompanying increased electricity consumption mentioned above is seen in Figure 3.6. This is particularly difficult for Ethiopia, which historically imported energy and suffers from recurring electricity shortages (Addis Fortune 2010).

While the upstream states are still far from being on par with Egypt in the realm of economic power[50], 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 micro-dams for irrigation needs of small farmers (Waterbury and Whittington 1998). The upstream states are strengthened additionally by the presence of new actors in the region which helps them to overcome the blockage of international funding from the traditional funding agencies like the World Bank by an Egyptian Veto – China and to some extent the Gulf countries. China is investing heavily in Africa as a whole 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[51]. They therefore have a special interest in Sudan because of its large potential of cultivatable land, and they especially support irrigation schemes (Cascão 2009).

In the concept 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 goals 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 (Cascão 2009). While the improvements discussed above are also true for Sudan, it so far maintains its alliance with Egypt (Zeitoun and Mirumachi 2008).

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[50] GDP if 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 Development Indicators 2009).

[51] This is sometimes called land grabbing. For more information see Cotula et al. (2009).

3.2.2 A Cautionary Note on Political Stability

In the literature often a decrease in armed conflicts as well as an increase in political stability is mentioned in connection to the economic improvements, but also as another factor of increasing (political) power (e.g. Cascão 2009)[52]. However, this is not strictly supported by the data. As shown in Figure 3.7, 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 even grimmer. 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. When looking at the development of the political stability from the Worldwide Governance Indicators (Figure 3.8) it has been consistently low, and Ethiopia has even seen a significant drop.

However, one indicator supporting some degree of increased stability is the increased stability of governments. Figure 3.7 also indicates the occurrence of coups d'état (black triangles). While they were prevalent in the 1970s (and also in the 1960s), Ethiopia and Uganda have not experienced one since the 1980s and the recent one in Sudan seems to be an isolated event[53]. Stability in the sense of providing services has improved in Ethiopia, where government effectiveness has increased significantly (Figure 3.9).

This theory is somewhat supported by the Polity IV Individual Country Regime Trends[54] (Figure 3.10) for Sudan and Uganda, who experienced many abrupt political changes before the end of the cold war, but few after. For Ethiopia however this is not seen. According to this score, all four states are now anocracies, and, except for Sudan, rather instable ones, confirming the Governance Indicators. Therefore this literature claim cannot be supported, and some caution seems warranted since the challenge to Egypt's hegemony occurs within a rather unstable political environment. Recurrence of violence would weaken the states again. However, also Egypt is rated unstable and violence is possible, especially once the current President Mubarak is out of office.

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[52] Research generally indicates that political stability is related to economic growth and development (Alesina et al. 1996, Feng 1997, Fosu 2004).

[53] The fact that Egypt has experienced its last coup in 1952 is another factor strengthening its political power.

[54] The polity scores measure regime authority on a scale from -10 (hereditary monarchy) to +10 (full democracy), where democratic and autocratic qualities in an authority are investigated together and at the same time. For more details see Marshall and Jaggers (2008) as well as the caption of Figure 3.10.

3.2.3 Cooperation or Conflict?

Interestingly this new situation of an upstream challenge has been met both by increasing cooperation as well as an increasing prevalence of unilateral acts. The latter can be seen as an attempt to put 'facts on the ground' to support claims to water. 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).

The cooperative approach is two-fold[55]. 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, focusing on 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 (Cascão 2009). 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[56], 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 without the agreement of Egypt and Sudan[57]. 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

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[55] The focus here is only on the most recent and most important initiative. For a more general overview of previous ones see Tesfaye (2008).

[56] 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)

[57] 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). It will be open for signature for one year.

sides. Kenya's Minister for Water Charity Ngilu was quoted as "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 funding to the signatories of the agreement[58] (Mayton 2010), but also offered more of its own aid to the upstream countries (Hamduillah and 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 are attempting to set the agenda. At this point it is too early to assess the impact these events will have on the relations in 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 (e.g. Mason 2004, Whittington 2004, Wichelns et al. 2003): HEP in Ethiopia[59], 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. In the impact graph in Figure 2.1 these cooperative interactions are indicated by the dashed lines connecting the "production" dimensions in each country (symbolic, as in detail impacts would also be on water and land availability as well as use). However, based on recent rhetoric this outcome currently seems unlikely, and a continuation of a challenged status-quo in a cold conflict is probable. The history of conflict is discussed in a causal chain framework in the next section.

3.3 A causal chain analysis

It has become clear in this chapter that the historic as well as current political situation in the Nile Basin is quite complex. The characterizing features are the large asymmetry between Egypt and the upstream states and the historic position of Egypt

[58] 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).

[59] 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).

as the dominating hydro-hegemon with 'historic rights' to 75% of the Nile waters. The occurrence of conflict and cooperation at different times can be analyzed in the framework of a causal chain (based on UNEP 2006) of

root causes → activities → immediate cause → conflict resolution capabilities → issue=conflict/cooperation.

For the core dispute between Ethiopia and Egypt this is shown in Table 3.1 for 3 main time periods[60]. The root causes, activities and immediate causes are based on the discussion in the previous sections. Conflict resolution capabilities can be seen as a factor deciding between the outcomes of conflict or cooperation, or on the strength of both, if they occur parallel. These capabilities are here mainly defined as initiatives and institutions which enable dialogue and build trust. If they are strong, conflict is less likely and cooperation more successful.

Since conflict and cooperation have always existed in parallel they are rated in the framework of the TWINS matrix (Zeitoun and Mirumachi 2008). The conflict can always be described as securitized, shifting on the Water Event Intensity Scale (Yoffe 2001) between -3 and -2, which means a cold conflict and unstable peace in the Conflict Intensity Frame (Zeitoun and Warner 2006). Cooperation between Egypt and Ethiopia was very limited initially (more between Egypt and Sudan/Uganda) since Ethiopia did not participate in previous initiatives (Arsano and Tamrat 2005). With the NBI and the CFA negotiations the era of truly parallel conflict and cooperation started, with active participation of Ethiopia, technical cooperation and some easing of the conflict. The recent opening of the signature process for the CFA draft has started a new chapter in the relations, where the hydro-hegemon is openly challenged, the conflict rhetoric has become somewhat tenser again and the future of cooperation is very unclear.

3.4 Conclusion

This chapter outlined the main challenges of the Nile Basin as the great asymmetries in the environmental, political, economic and developmental dimensions, limited

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[60] Sudan became Egypt's ally with the 1959 agreement (unwilling at times due to a perception of being treated unfairly (Zeitoun and Mirumachi 2008), but also benefiting from an, in relative terms, rather large share granted (Waterbury 2002)). Uganda, after the agreement with Egypt on construction of the Owen Falls Dam in 1953, became Egypt's "unwilling ally" (Waterbury 2002) and, as has been mentioned before, the White Nile is not nearly as important for Egypt as the Blue Nile unless the Jonglei canal would be build.

water availability and population pressure. Here the link between the environment, the socio-economic framework and the occurrence of conflict and cooperation is visible, illustrated by the impact graph of Chapter 2 and the causal chain of this chapter. The interstate relations are shaped by Egypt's status as dominant hydro-hegemon, insisting on its historic rights and the principle of no harm. However, the upstream states have improved their capacities especially in the economic and bargaining power dimension as well as exploitation potential and now contest the hydro-hegemony, emphasizing the principle of equitable use. While cooperation has increased, this is tested now by the one-sided signing of the CFA without approval of Sudan and Egypt. The future is unclear, though armed conflict seems unlikely at this point.

Chapter 4: The Influence of Climate on Water and Land Availability and the Vulnerability of the Nile Basin Countries to Climate Change

The previous chapter illustrated increasing population pressure and large asymmetries as major challenges with respect to sharing the waters of the Nile, while showing increasing ability for upstream countries to challenge the status quo. The availability of water and usable land is determined by climatic conditions and can be affected by a changing climate. This connection will be discussed in this chapter. The first section gives a brief overview over the climate in the four countries. After that the current knowledge of the expected effects of climate change in the region are summarized, and possibly already visible impacts are presented. Finally the vulnerability of the countries to the effects of a variable and changing climate is discussed, since it is the decisive factor determining the socio-economic impact of climate change and therefore affects the possible link to conflict.

4.1 Climatic Conditions in the Nile Countries and their Impact on the Nile Flow

The basic factors influencing water and land availability (which are represented by the box "climate" in Figure 2.1) are temperature, precipitation patterns and evaporation. They will be discusses briefly for each country in the following (all data from Aquastat 2010 Country Profiles).

Uganda is characterized by an equatorial tropical climate (partially moderated because of relatively high altitudes towards the south) with generally high humidity (70-100%) and high temperatures (annual mean 18-35°C, warmer towards the north). While rain falls almost year-round in the south with peaks of 1500 mm/yr close to Lake Victoria, the north experiences a dry season from November to March and has rainfall of around 750 mm/yr. Rainfall varies strongly inter-annually and is mainly influenced by the migration of the Inter-Tropical Convergence Zone (Conway and Hulme 1993). Lake Victoria is an important water source for the country and also the source of the White Nile. It is fed by tributary rivers from Rwanda, Burundi and Tanzania. Lake levels are very sensitive to rainfall in the region since evaporation over the lake is almost in balance with rainfall over the lake (Sutcliffe and Parks 1999). Between 1961 and 1965 an impressive rise in lake level was caused by high rainfalls, doubling the lake's outflows in the 1961-1990 period compared to 1931-1960 (Conway 2005). More recently, most noticeably since 2006, lake levels are dropping again and might return to pre-1960 values (Awange et al. 2008)[61].

The climate of Ethiopia is a tropical monsoon climate with large differences between the high plateaus (7-12°C mean annual temperature) and the hot lowlands (>25°C mean annual temperature) with a temperate zone between 1500 and 2400 m above sea level. While rainfall is abundant in the national average (annual average of 848 mm), it is highly variable both spatially and temporally, leading to strong floods as well as droughts. The wet season, which also gives rise to the Blue Nile flood, occurs between June and September. In the high altitude source region of the Blue Nile average annual rainfall ranges between 1400 and 1800 mm, while it is about 1000 mm near the border with Sudan (Sutcliffe and Parks 1999). Evaporation is rather high in the border region but lower in the highlands. There the strong rainfall events and the steep topography lead to a high degree of soil erosion, with 31% of the soil area at risk (Terrastat 2010).

Sudan extends from areas with equatorial climate in the south through an area with summer rains to desert climate in the north. Temperatures vary between 30-40°C in summer and 10-25°C in winter. Rainfall is regionally dependent and decreases from up to 1600 mm/yr in the south[62] to 300-500 mm/yr in the central regions down to

[61] This drop however cannot simply be attributed to a changing climate. According to Kull (2006), it is 55% man-made, due to large releases at the Owen Falls dam on the White Nile north of the lake.

[62] There the large wetlands can be found, like the Sudd swamp, where precipitation is high but largely evaporates again quickly.

only 25 mm/yr in the north. Evaporation increases towards the north with increasing temperatures - northern Sudan and Egypt have the highest degree of evaporation in the basin leading to significant loss of water in Lake Nasser (around 10 km^3/yr, Sutcliffe and Parks 1999). Agriculture is concentrated in central Sudan, but hindered by a dry season lasting about 8 months.

Egypt has a desert climate with mild winters and very hot summers (temperatures ranging from a maximum of 32°C at the Mediterranean coast to over 40°C in the south). There is very little rainfall overall, with almost none in the south and about 200 mm/yr in the coastal regions.

The atmospheric variables discussed above (temperature, precipitation, evaporation), together with land cover and topography, are the main determinants of river flow. Flow corresponds to the difference between precipitation and evaporation and is especially sensitive to the former with a strongly non-linear relationship (Conway and Hulme 1993). Since Egypt and Sudan have little rainfall, they contribute almost no water to the Nile, whose flow is therefore largely governed by the conditions in the headwater regions (Ethiopia and the equatorial lakes region). As has been mentioned already in Chapter 2, for the downstream countries the Blue Nile is decisive since the contribution of the White Nile to the total flow is limited by large evaporation in the Sudd swamps. Since climate change primarily affects temperature and precipitation, the flow of the Nile could also be altered. Additionally, Egypt will be affected by climate-induced sea level rise. These effects will be discussed in the following section.

4.2 Climate Change in the Nile Region: Observed Trends

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).

For precipitation trends are harder to observe due to an inherent high inter-annual and inter-decadal variability, and a high sensitivity[63] of both the Ethiopian Highlands and the equatorial lakes region to even small climate variations (Elshamy et al.

[63] 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” (IPCC 2007a). This can be a direct or indirect effect.

2009b)[64]. No statistically significant trend can be seen for the precipitation changes in Ethiopia from 1960-2000 (McSweeney et al. 2010, Ethiopia profile, see also Figure 4.1), though there are some indications that variability is increasing (FEWS NET 2003)[65].

Rainfall over the equatorial lakes is uncorrelated with Ethiopian precipitation (Conway and Hulme 1993). 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 trend would be visible which could be attributed to climate change, since changes in overall rainfall are so far minimal.

4.3 Changing Climate in the Nile Region: Predictions for the Future

Future projections for the climate[66] are based on the emission scenario[67] 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 rises in the north of the basin (Egypt and northern Sudan) than in the south (Elshamy et al. 2009b, Kim and 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 works on the Blue Nile catchment region report conflictive results. For the 2090s rainfall reductions are predicted in 10 out of 17 GCM models by El-

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[64] 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).

[65] It is interesting that several studies show that a change towards less reliable rainfall and different rain periods is clearly observed in the perception of the rural population. However, this does not seem to be necessarily supported by rainfall data, which could be due to a lack of data, but also changes in the need for water (Meze-Hausken 2004, Regassa et al. 2010).

[66] 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).

[67] The "Special Report on Emissions Scenarios" contains 40 scenarios on how emissions might develop depending on the level of integration in the world and the level of greenhouse gas emission, as well as other driving forces. The A1 and B1 scenarios describe a convergent integrated world compared to a locally rather than globally oriented world in A2 and B2. The B scenarios are more ecologically friendly than the A scenarios. See Nakicenovic and Swart (2001) for more information.

shamy et al. (2009a), 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%[68]. According to McSweeney et al. (2010) there is an increasing proportion of rain falling in heavy events[69].

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 (and the opposite, Conway and Hulme 1993, Elshamy et al. 2009a). Runoff is therefore even harder to predict. For the upper Blue Nile the ensemble means of Kim and Kaluarachchi (2009) and Elshamy et al. (2009) are +4% and -15% respectively, 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 and vary wildly in the literature (Elshamy et al. (2009b): -62% to +43% with ensemble mean of +1%, Conway (2005): dry and wet case of -9% to +15% for 2025, Strzepek et al. (2001): -90% to +18% in the 2090s).

Egypt is the only country in the Nile Basin threatened by sea-level rise, but that threat is high 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 could be found. According to Nicholls et al. (2007) until 2100 a rise between 0.28 and 0.43 m is expected, depending on the emission scenario. However, sea level rise due to thermal expansion is expected to go on for very long, even if mitigation measures were taken now. So the long-term effects are unclear.

4.4 The Vulnerability of the Nile Basin Countries to a Changing Climate

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

[68] Differences can be due to different emission scenarios used: Elshamy et al. (2009) use A1B, Kim and Kaluarachchi (2009) use A2.

[69] 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 athmosphere, 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 et al. 2002).

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." (IPCC 2007a). According to this definition the three determining factors for vulnerability are exposure, sensitivity and adaptive capacity[70]. These three dimensions will be assessed in this section.

4.4.1 Exposure

Exposure is high in all Nile countries. The upstream countries already suffer from a highly variable climate with frequent droughts and floods, and climate change is likely to increase this variability, the frequency and strength of extreme events (Conway 2005), as well as make conditions more unpredictable in the long term, specifically with respect to rainfall. Some evidence of this can already be seen in Sudan and Ethiopia (Regassa et al. 2010, Zakieldeen 2009). Egypt is highly endangered by sea level rise. Rising temperatures are expected for all countries. The sectors mainly impacted by a variable and changing climate are water, health, agriculture, food security, infrastructure and the economy.

4.4.2 Sensitivity

Sensitivity is also high. Upstream countries largely depend on agriculture and climate change is expected to have a large impact on agriculture by changing the crop yield, the water requirements, growing seasons and the occurrence of crop diseases. The predictions vary widely and depend highly on specific local conditions and on the type of crop, but in general a reduction of crop yields and production is expected for Africa and the Nile countries, with a possible exception in the highlands[71]. Cash crops will be affected by this, like coffee in Uganda (Hepworth and Goulden 2008). It will also have a tremendous impact on food security and will be exacerbated by the frequent occurrence of floods and droughts. As can be seen from Table 4.1, sensitivity to these events, in the upstream countries particularly, is rather large, with high numbers of affected people and deaths. Strong floods and heavy rain can increase erosion, particularly in Ethiopia. Additionally infrastructure can be damaged by such

[70]Adaptation means the measures taken in response to the effects of climate change, including expected effects. These measures can be directed towards minimizing harm, compensating for negative impacts or utilizing positive effects (Scheffran 2010).

[71] More details can be found in studies by Fischer et al. (2005) on Africa, by Thornton et al. (2009) for Eastern Africa, by Mideksa (2010) and Deressa and Hassan (2009) on Ethiopia and Eid et al. (2006) by on Egypt.

events, and the combination of destruction and reduced production in the most important economic sector will strongly affect economy, hindering development.

Infrastructure and agriculture are also endangered by sea level rise in Egypt. For a rise of 1 m, an impact of 6% on the GDP and of 6.1 Mio displaced people is estimated (Dasgupta et al. 2007). Additionally, saltwater intrusion affects groundwater and land further inland, and the coasts are weakened.

The water sector is impacted by higher unpredictability (more erratic rainfall, which is already seen in Sudan, Zakieldeen 2009) and frequent changes of water levels in lakes and reservoirs. 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 (also due to higher lake temperatures) and HEP produced at Owen Falls Dam, which is Uganda's major source for electricity (Hepworth and Goulden 2008). HEP as a factor for development is therefore also affected by climate change[72]. On the demand side, an increase in water use due to increasing temperatures is likely in all sectors (human demand, industrial demand for example for cooling purposes, and irrigation). This means increasing "pressure on water resources already under pressure" (Goulden et al. 2009:7).

Finally, in the health sector the main impact is an expected spread in the occurrence of malaria due to higher temperatures (Pascual et al. 2006)[73]. Also respiratory disease (due to higher temperature) or water borne disease (in connection to floods) could increase, as well as problems related to malnutrition.

4.4.3 Adaptive Capacity

Vulnerability is high, but also influenced by the ability to adapt, and adaptive options are available for many of these problems. They include a clear strategy for water management or changes in agricultural patterns (for example using less water intensive crops or crops which are resilient to higher salt levels or drought).

In the Nile countries, adaptive capacity is unequally distributed. Important determinants for adaptive capacity are the availability and distribution of resources, the range of available technological options, human and social capital, institutional structures and their decision making criteria, and the management of information (Yohe

[72] Another example is the drought reducing the operation of the Ethiopian Tekezze dam in its first year of operation, which so far has not produced even close to capacity (Abate 2010).

[73] However, this is not uncontested and part of an ongoing debate – see Gething et al. (2010) for an opposite opinion.

and Tol 2002). Egypt has a clear advantage in most of these categories, and the Aswan High Dam is a prime example of successful adaptation to variable conditions[74]. However, due to Egypt's dependence on external water resources, the adaptation actions in the water sector need to shift from a purely supply-focused to an integrated approach. Also adaptation to sea level rise requires a large amount of investment, innovation and clear strategies on internal migration and urbanization, which is a formidable task.

The upstream countries on the other hand are disadvantaged in most of the determining categories. While the people already have experience in adaptation to variable conditions they can build on, it is also clear from the devastating consequences shown in Table 4.1 that this is not always successful and might not be sufficient for increasing magnitudes of variation. For these countries (and for their donors) it is important to take climate change into account in their current development strategies. Especially with respect to the construction of dams, irrigation schemes and large-scale agricultural projects a high degree of flexibility has to be build into the infrastructure to be able to function under more variable and changing conditions which are not easily predictable. This requires strong leadership and institutions, which currently seem to be lacking.

4.5 Conclusion

Clearly, climate has a strong impact on the availability of resources like land and water. Climate in the source regions of the Nile determines its flow volume. The climatic conditions also influence the conditions for agricultural production and human wellbeing. Despite many uncertainties with respect to the effects of climate change, warming trends are already observed in the region. Further warming of the Nile region is inevitable, and together with the rest of Africa it will be larger than the global mean (Christensen et al. 2007). While it is not clear yet if large scale changes in annual precipitation will occur, the already existing high variability is likely to increase together with extreme events like floods and droughts, impacting strongly on river flow. Within the range of the models, large changes in both directions for flows and therefore water availability are possible.

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[74] It was key in mitigating the effects of the large drought in the 1980s (Gasser and Abdou 1989).

A large degree of flexibility is necessary for successful adaptation[75] to such changing conditions, depending on the degree of vulnerability of the Nile Basin societies. From the discussion it is clear the upstream states are more vulnerable, largely due to higher sensitivity and lower adaptive capacity, but Egypt as well faces many challenges. The most strongly affected sectors, water and agriculture, are also the ones crucial for the conflictive situation described in Chapter 3. Therefore in the next chapter the impact of climate change on conflict and cooperation will be assessed.

Chapter 5: Can climate change have an impact on the power play in the Nile Basin?

In the previous chapters the links between the various factors in the impact graph were explored, and the occurrence of conflict and cooperation as well as climate, climate change and the factor of vulnerability were discussed. Now these different pieces are synthesized in order to explore the question if climate change, through the link of water/land availability, can have an impact on conflict or cooperation in the Nile Basin. This discussion is focused on the question of water, since that is the major cause for controversy.

The hypothesis is that climate change influences the causal chain developed in Section 3.3 on the levels of root causes, activities and immediate causes. The root cause of limited water availability is affected through impacts on the supply as well as demand side of water. On the level of activities the impact is in terms of the viability of cooperative solutions to the conflict, like the effectiveness of dams and irrigation projects as well as of treaties. Finally climate change could be an immediate cause for conflict or facilitate cooperation. This is discussed in the following three sections. A preliminary result of the use of the agent-based model is shown in Section 5.4 before concluding the chapter.

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[75]Adaptation means the measures taken in response to the effects of climate change, including expected effects. These measures can be directed towards minimizing harm, compensating for negative impacts or utilizing positive effects (Scheffran 2010).

5.1 The Impact of Climate Change on Water Availability

Since this is a complex discussion, the most important linkages are shown in an overview graph in Figure 5.1.

5.1.1 Water Supply

As has been mentioned already in Chapter 4, no reliable predictions can currently be made on the impacts of the flow of the Nile in the future. A reduction in total flow would increase water scarcity for the whole basin. For the upstream states this would increase the need to use Nile water since in that case probably also their other water sources would be diminished, including soil water. At the same time some projects, especially HEP dams, might no longer be viable. Downstream it would likely be impossible to maintain the status quo. Egypt could either join the CFA, cooperate and adapt to the lower water quota (for example by implementing changes in its agricultural sector, including possible reductions), or it would have to use great pressure to prevent further unilateral projects upstream. The latter path might lead to armed conflict as well. Even in the cooperative case it could be much more difficult to come to an agreement under even tighter conditions than those existing today.

An increase in total flow would not be without problems either. It would likely make it easier to cooperate, since additional water could be used by the upstream countries while Egypt could maintain its current quota. However, a higher flow might overwhelm the capacities of dams (existing and future ones unless they take this possibility into account), infrastructure on the river banks might be endangered, and siltation might increase. A strong increase in cooperation over water projects would be needed to ensure efficiency.

Finally an increase in variability is a threat even when the total flow does not change. More floods and droughts make dam operations more challenging, some non-viable, and require a good cooperation in the management of dams. Especially for Sudan, which suffers greatly from the floods of the Nile, cooperation with Ethiopia could become more and more attractive, leaving Egypt on its own unless it backs down from the status quo. Prolonged droughts can also endanger Egypt, as was shown in 1988, when Egypt barely avoided a major water shortage (Conway 2005).

Clearly, changes on the supply side could be managed, but probably require increased levels of cooperation, including joint management of dams. Insisting on the status quo might endanger Egypt, and, for large reductions in flow, might even tempt it to use force. However, this is the most unlikely scenario.

5.1.2 Water Demand

Water demand most likely will rise when temperatures rise if no adaptation takes place. This could exacerbate scarcity resulting from population growth. In the worst case it could lead to stronger efforts in the upstream states to use Nile water at the same time as it could strengthen Egypt's point of view that it is unable to reduce its allocation. Great scarcity could even lead to stronger pushes to prevent other states from using water and to strongly increase the own water use in a unilateral way. This would increase the likelihood for conflict, maybe even armed.

On the other hand it might push Egypt to finally acknowledge its options to reduce demand (in the agricultural sector for example, or in the desert reclamation projects[76]) and search for alternative sources (treatment of wastewater, desalination), since otherwise the gap between demand and supply could become difficult to bridge.

Upstream clearly the need for water development will increase further, but it is of great importance that this development is "climate proof", especially with respect to irrigation schemes and the type of agricultural projects (type of crops, location etc). If development plans are made on the basis of the current climate and past long-time records they might not be suitable under climate change (Milly et al. 2008). Again this would benefit from enhanced cooperation, since increasing resource pressure makes it even more attractive to make use of the comparative advantages each country has. Especially with respect to food security, the use of the most promising regions (taking into account climate change) and related inner-basin trade is probably the more promising option compared to irrigation schemes in each country with potentially low efficiencies. Also, increasing development should result in a shift in importance from agriculture to other sectors, with respect to GDP as well as in the work force, to decrease sensitivity.

One way of mitigating increased demand is the import of 'virtual water', that is food stuffs which would require substantial amounts of water if they were to be grown domestically (Allan 1996a, 1996b, 1998). As was already mentioned above, Egypt

[76] The Toshka project can be considered to be maladaptive since it reduces the flexibility needed to respond to climate change (Conway 2005).

imports substantial amounts of food and through this also significantly alleviates its water scarcity. This is only possible due to its good economic standing, and therefore not currently an option for most of the upstream states. Further economic development is therefore important for them also in this respect. The virtual water import is illustrated in Figure 5.2. Sudan imports very little virtual water, Uganda even exports it and Ethiopia's share in virtual water trade is negligible. It is interesting to see that most of the trade is not within the basin but with the rest of the world. As mentioned above there lays an opportunity for increased cooperation between the Nile states which could create interdependencies and decrease the risk of conflict.

The conflictive or cooperation potential of increasing demand is intertwined with development of supply. Increased demand could be mitigated by increased supply, however that might reduce the opportunities for reallocations without changes for Egypt. A reduced supply could increase the likelihood for conflict, since the compromises the countries would have to make to share the smaller amount of water equitably might be too much to bear. The expected higher variability also poses a challenge in combination with higher demand, since for example droughts could be even more destructive than now. For all Nile Basin countries, strong efforts in demand-side management are of prime importance.

5.2 Cooperation Schemes under Climate Change

5.2.1 Technical Cooperation

Climate change can impact existing and planned cooperation projects and schemes, in a negative or a positive way. Current cooperation is mostly on the technical level, but with the goal to share benefits. Examples are in the area of electricity, irrigation and flood protection (Goulden et al. 2009). Wichelns et al. (2003) name the comparative advantages of the countries as growth of cash crops and provision of upstream investment in Egypt, food production in Sudan and livestock and HEP in Ethiopia (Uganda is not included). In general upstream storage is often named as an advantage due to lower evaporation. Under climate change some of these projects might become less viable.

Agriculture in Egypt and Sudan will likely become more challenging. While the shift from food crops to cash crops still would be useful in Egypt, the future scope for agriculture in both countries is unclear. Sudan's agricultural potential might be

strongly reduced. The import of virtual water might become more and more crucial for all basin countries.
The difficulties for HEP with increased water variability have already been mentioned above. The cost-benefit ratio of large dams under climate change is also questioned by Block et al. (2007). On the other hand flood protection is important for downstream states, in general and especially in case of higher floods. A combination of microdams and mini-HEP projects (Hepworth and Goulden 2008, Waterbury 2002) and few well-placed large-scale projects would likely be advantageous. However, large gains in terms of reduced evaporation are then unlikely, especially since the best locations for such dams are at rather low elevation (Waterbury 2002).
The conditions for livestock in Ethiopia could improve with increasing rainfall, but worsen if rainfall decreases, or in times of drought, since mobility to search for pasture is reduced due to population pressure. Ethiopia in general will probably be in large need of outside support for adaptation, as it is already the weakest country in the region.

5.2.2 Cooperation Treaties

Climate change can influence the stability of a cooperation agreement on transboundary water resources. A study by Ansink and Ruijs (2008), using a game-theoretic model, showed that a decrease in water flow will destabilize agreements, and increases in variability could have either stabilizing or destabilizing effects.
Cooperation in terms of international arrangements and treaties can be limiting or negative in a number of ways, for example with respect to transparency, inclusivity, data quality, equitability, environmental sustainability or implementation (Kistin 2006 as cited by Goulden et al. 2009). According to Fischhendler (2004), treaties can be specifically negative with respect to climate change when they do not provide enough flexibility to address the uncertainty in climate change predictions, and the increasing variability expected. In that case they can become ineffective, unsustainable or even dangerous 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 (Cooley et al. 2009). According to Ansink and Ruijs (2008) a fixed allocation regime is the least stable regime.

In the Nile Basin the major currently valid treaty on water is the 1959 treaty between Egypt and Sudan. According to these criteria, this treaty could be considered rather positive. While it has fixed allocations, there are mechanisms to change these for extreme events and future demands. This could be considered a review procedure. It happens in the framework of the Permanent Joint Technical Committee, a joint management institution. Therefore it could be considered promising. However, of course this agreement is neither equitable nor inclusive, and when the review process was tested by a request from the upstream states in 1961 for the allocation of 5 BCM, this was rejected (Waterbury 2002).

While Egypt's main interest is to uphold this agreement, Sudan increasingly is interested in developing its own potential for which much more water is needed than its 1959 allocation (Cascão 2009). The temptation of a closer cooperation with Ethiopia (Waterbury 2002) might be increased under the challenges of climate change, especially in the area of flood control. The new CFA could even provide an easy way out for Sudan.

It is not possible to assess if the CFA is "climate-proof" since the text is not publicly available. If climate change was not taken into account for it, it's long-term capacity to solve the problems of the Nile Basin is greatly diminished, even if it enters into force.

The basin as a whole is clearly far from an ideal preparation for climate change, due to the lack of a basin-wide agreement. The NBI however can be seen as a very positive factor. While so far climate change has not been covered 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 sharing of benefits has created capacities which are useful also in the context of climate change mitigation and adaptation (Cooley et al. 2009). Currently a concrete project is being developed to work on climate change impacts and adaptation within the NBI (NBI 2008). If the CFA would enter 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, which could also possibly review the CFA in terms of the criteria above. The future of the NBI is uncertain if Egypt and Sudan do not join the CFA, which would increase the difficulties to improve the adaptive capacity in the Nile countries.

5.3 A direct impact of climate change on conflict or cooperation?

From the previous two sections it is already clear that countries can benefit strongly when adaptive measures to climate change are undertaken cooperatively. There are two more direct ways that climate change can lead to conflict or cooperation (Goulden et al. 2009).

Climate change can be a facilitator of cooperation through disasters like floods and droughts which can lead to a breakthrough in negotiations (Huisman et al. 2000). However, such disasters already happen on a frequent basis in the Nile Basin without any 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 water in Lake Nasser. This could push it to more cooperation, but at this point this option seems unlikely.

Unilateral adaptation measures to climate change can also have a direct impact on the possibility for adaptation in other countries and therefore cause conflict (Goulden et al. 2009). This is of course what currently happens already in the Nile Basin, with unilateral water development projects being implemented, even without climate change being invoked as a motivation[77]. Again, as climate change intensifies, the impacts of such projects on the other countries could be stronger and increase the motivation even for armed conflict. A more likely process could be the ongoing securitization of climate change in the Nile Basin, which means a stronger instrumentalization of the vulnerability to climate change to justify actions and strengthen ideational power.

Overall climate change as an immediate cause for conflict or cooperation in the Nile Basin is rather unlikely.

5.4 An Exemplary Illustration with the Agent-Based Model

The agent-based model, described in detail in Scheffran et al. (2010), can be used to illustrate different scenarios under climate change. The basic structure of the model is shown in Figure 5.3. In order to achieve goals for water supply, the countries can either invest in reducing national water consumption, in internal water supply, in

[77] Upstream dams reducing downstream supply can be considered as adaptation to variability and the Egyptian land reclamation projects could be considered adaptation to rising sea levels (Conway 2005).

collaboration with upstream countries to increase external supply, or in threats to another country to prevent it from decreasing supply. The other country can choose to accept or resist this threat. While the model still lacks complexity, for example with respect to costs of investment, it can still be used to illustrate possible investment opportunities. This is done for the following scenario: Egypt seeks to keep its per capita consumption constant (symbolizing its desire to keep its current quota), Sudan, Ethiopia and Uganda would like to increase their per capita consumption to 500 m^3/yr, the minimum level to avoid severe water stress (Falkenmark et al. 1989). The model runs over 20 years, and a baseline, a positive (+ 20% water) and a negative (-20% water) climate change scenario are applied.

The results are shown in Figure 5.4. For Ethiopia and Uganda climate change makes no difference. They have to invest heavily either way since they start out far below their goal. For Sudan, initially differences can be seen, but they converge, since it is not far from its goal. Egypt, to keep its per capita supply, can decrease investment rather quickly if the overall water supply increases, but decreasing supply affects it strongly by requiring continuously rising investments. Nothing can be said about conflict or cooperation strategies, since the costs for these options are not yet dynamic.

These results are preliminary and only meant to illustrate one possible use of the model. It can prove highly useful for the exploration of scenarios, with and without climate change. The validity and cost of certain goals can be analyzed as well as in the future different options to achieve these goals, including cooperation of all or some subset of countries. This will provide new options to study the Nile Basin.

5.5 Conclusion

In summary, the causal chain leading to conflict and cooperation in the Nile Basin, and therefore the power play between the states, is affected by climate change in several ways, and scenarios for greater conflict as well as greater cooperation can be deduced. While a direct link is highly unlikely, the indirect effects could be strong.

Cooperation can be hindered or facilitated by climate change. On the one hand, cooperation seems to be more important than ever, and efficient adaptation can probably only be reached under strong cooperation, especially under increasingly variable conditions. Higher flows might reduce the barriers for cooperation (unless they are balanced by higher demand). However, in the case of lower flows, while cooperation would be key to achieve the best adaptation possible, based on the current political events and rhetoric it seems unlikely that cooperation could be achieved between upstream countries and Egypt unless much higher incentives are created. This could include strong outside encouragement or even pressure, as well as conditional external financial support (Wolf 1998). One particular incentive for Egypt to join a cooperation scheme 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 affect the developing upstream capacities to challenge Egypt's hydro-hegemony and therefore reduce cooperation incentives for Egypt.

Any basin-wide treaty can only be sustainable under climate change if it includes provisions as mentioned in Section 5.3.2. Flexibility is the key ingredient, for agreements as well as infrastructure and institutions. However, flexibility in agreements can endanger enforceability and reduce reliability of expected water flows. This was investigated by Drieschova et al. (2008), who found that this trade-off is part of the reason why so many agreements are rather broad. According to their analysis, the best solution is water allocations based on percentages. They can be enforced, but at the same time also adapted to changing flows. This can only be successful when transparent conflict resolution mechanisms are installed to address disagreements.

The most likely and immediate impact of climate change on the riparian relations might be its instrumentalization either by a securitization of climate change itself, or by an enhanced securitization of water. Some hints of this might already be seen in the media, though a detailed analysis is beyond the scope of this thesis.

Chapter 6: Conclusion, Limitations and Future Prospects

This thesis is related to an ongoing effort to apply agent-based modeling as a new approach to understand the occurrence of conflict and cooperation in the Nile Basin as potential impacts of climate change. In the first approach the focus lies on interstate relations. In this framework, this thesis provides a detailed and empirical discussion of the impact graph, which is the basis of the model concept. A comprehensive approach is employed, linking environmental and human dimension with a focus on land and water. This is presented in Chapter 2.

This is accompanied in Chapter 3 by a discussion of the historic and present interstate relations, analyzed in the theoretical framework of hydro-hegemony. Using a causal chain analysis and focusing on the core conflict between Egypt and Ethiopia, three periods in the relations are outlined: (1) the period of dominant hydro-hegemony marked by little cooperation and cold conflict, (2) a shift to contested hydro-hegemony with increasing upstream potential to challenge Egypt, but marked by increasing efforts of cooperation, (3) the latest period of openly contested hydro-hegemony. The Nile Basin is found to be an exemplary case for the validity of the new stream of water conflict literature – the parallel occurrence of conflict and cooperation. Here, more research seems warranted to better understand what pushes states to emphasize one or the other and what incentives the Nile states need to cooperate more effectively.

In light of the guiding question for this first part, which is formulated in Section 1.2, the impact graph in combination with the causal chain illustrates the linkages between environmental conditions, the human dimension and the occurrence of conflict or cooperation, with conflict resolution capabilities as a decisive factor between the two options. These linkages are complex and the root causes for the tensions stem from all dimensions: a basin-wide limitation of water resources, environmental as well as political, economic and developmental asymmetries, population pressure and the need for upstream development. Feedback effects between these factors exist and are also outlined. The factors are illustrated empirically, together with the more immediate cause of tension, which are the improving capacities of the upstream states to exploit their potentials. Interestingly, the often claimed improved political stability is found to be difficult to support with the given data.

Chapters 4 and 5 focus on the new challenge in the Nile Basin: climate change. In Chapter 4 the factor climate is linked to the environment in the impact diagram. Observed and predicted trends for climate change are presented, and the vulnerability of states is assessed. A high vulnerability is found in all Nile countries, somewhat mitigated by higher adaptive capacities in Egypt, and largely in the sectors water and agriculture – the main focal points for tensions in the basin.

Finally, Chapter 5 discusses the question of an influence of climate change on the interstate relations in the Nile Basin, based on its possible impact on three elements of the causal chain, and with a primary focus on water. It is found that, while there is the possibility of increased, or even armed, conflict, this seems unlikely based on the past actions of the states. Investments in water demand-side management are important, and the benefits of stronger cooperation are likely to increase under climate change. However, all one-sided as well as cooperative efforts of development should take climate change into account to avoid loss of viability. An examination of the new CFA in this respect would be very interesting.

In line with other research it is found to be unlikely that climate change itself could be an immediate cause for conflict and cooperation. A further securitization and instrumentalization of climate change by the Nile countries seems very likely, especially in the strife of upstream countries to challenge the hydro-hegemon, and in Egypt's strategies to resist this challenge.

Therefore, the hypothesis formulated in Section 1.2 is found to be true: climate change can alter conditions for conflict and cooperation, but an influence as immediate cause is highly unlikely. The strength of the impact cannot be quantified in this thesis, but the agent-based model, an exemplary use of which is shown in Section 5.4, could be a tool to assess this.

6.1 Problems, Limitations and a Warning

Several limitations should be mentioned for this work. First, the focus lies on the interstate level, somewhat driven by a lack of subnational data. Climate change is thought to be more likely to be related to low level, small scale violence and conflict (like communal violence or conflicts between herders and farmers), making this an important research area. Also, such disturbances could weaken states, possibly create spill-over effects and therefore have an impact on interstate relations. Consequently, these issues should be addressed in future research of the Nile states, but improved data and a much better understanding of the internal situation of the countries are necessary. The agent-based model will be developed further and could be well suited for such research questions.

Secondly, only four countries of the Nile Basin are considered in this thesis. While this choice is well motivated, the southern states should be examined in the future, since they have an impact (see CFA). They also have their own conflict potential

over the tributaries and the use of Lake Victoria. Also, the role of Sudan, treated largely as an Egyptian ally in this work, should be differentiated to a greater extent.
Thirdly, climate change occurs on long timescales. Especially in the Nile region it is difficult to differentiate climate change impacts from natural variability. Politicians, acting on short time scales and facing the tremendous existing challenges, might find it unwarranted to add another, highly uncertain problem to their agenda. Also, the people of the region have always been facing climate variability and have developed traditional adaptive capacities.
However, a "no regrets" argument can be employed here: many developmental projects as well as cooperation agreements, which happen in any case, can only benefit from being flexible enough to adapt to any change or variability affecting them. In that sense, climate is as important as climate change and research with respect to both can be performed together. Since these projects are realized now, strategies for them should be developed now as well. The uncertainties of climate change are no reason to wait, particularly since effective adaptation has to start now, and it can be integrated into ongoing development. Likely and unlikely impacts of climate change should be identified to prevent a securitization and instrumentalization of the issue.
A final cautionary note: in the discussion of the links of climate change and conflict it should be recognized that there are high uncertainties in the computer simulations. Therefore a range of possible scenarios should be discussed. Also, there is a difficulty in linking the variables predicted in the simulations (rainfall and temperatures) with socio-economically relevant variables such as river flow or crop yields. This caveat needs to be taken into account and addressed. In that respect, more research for climate change predictions on a country or even subnational level is desirable.

6.2 Future Research Prospects

Besides the issues mentioned in the previous two sections as warranting future research, three main points should be highlighted here. The first is the role of Sudan as "master of the middle" (Waterbury 2002), having incentives both to keep the alliance with Egypt and to cooperate more closely with Ethiopia. It has an unique option to be an intermediate between upstream and downstream, and maybe even has the power to convince Egypt to join the CFA[78]. Of course, it is also highly unstable, faces multiple armed conflicts, and is highly vulnerable to climate change. The agent-based model could be used to investigate Sudan's options, and a project related to the impact of next year's referendum on the independence of South Sudan would be very interesting.

Second, the existing traditional adaptation methods in the Nile countries would be a very interesting research project. Issues to be addressed include their effectiveness, thresholds for their failure and how they can be used as possible foundation for adaptation to climate change.

Finally, the investigation of the role of renewable energies in the development of these countries is highly interesting. The potential is high. HEP is already used and the most prominent example, but it has its own problems related to the large dams. A newly proposed option is solar-thermal power, most prominently the Desertec project (Desertec Foundation 2009). It has the potential to strongly affect the Nile region. Currently, from the Nile countries only Egypt is part of the concept. This gives Egypt again an advantage over the other countries and further tightens its relations with Europe. On the other hand, this could be another point of cooperation, if Egypt supports an involvement of the upstream states or transfers the related knowledge and technology upstream. Also, since the solar-thermal plants can be coupled to desalination projects and can provide area for agriculture under the solar panels, they can be a contribution to reducing Egypt's dependence on the Nile water, possibly easing tensions. At the same time this new source of clean power might reduce Ethiopia's comparative advantage as an exporter of HEP to Egypt, reducing this cooperative option. Also, the experiences with HEP dams as another example of projects with large impacts could provide some lessons for the Desertec project.

At this point it is probably too early to really assess any of these impacts confidently, since the project is still in its initial phase. Nevertheless, they should be taken into account early on to avoid negative effects and promote the positive options. This thesis provides a good foundation to assess the Desertec project in this respect.

[78] Currently it does not look like it is interested in leaving the alliance though, since it has even announced to freeze its NBI membership until the current controversy is solved (Sudan Tribune 2010).

Appendix A: Figures and Tables

A.1: Chapter 1

Figure 1.1: Hydrological map of the Nile Basin (taken from World Bank 2010).

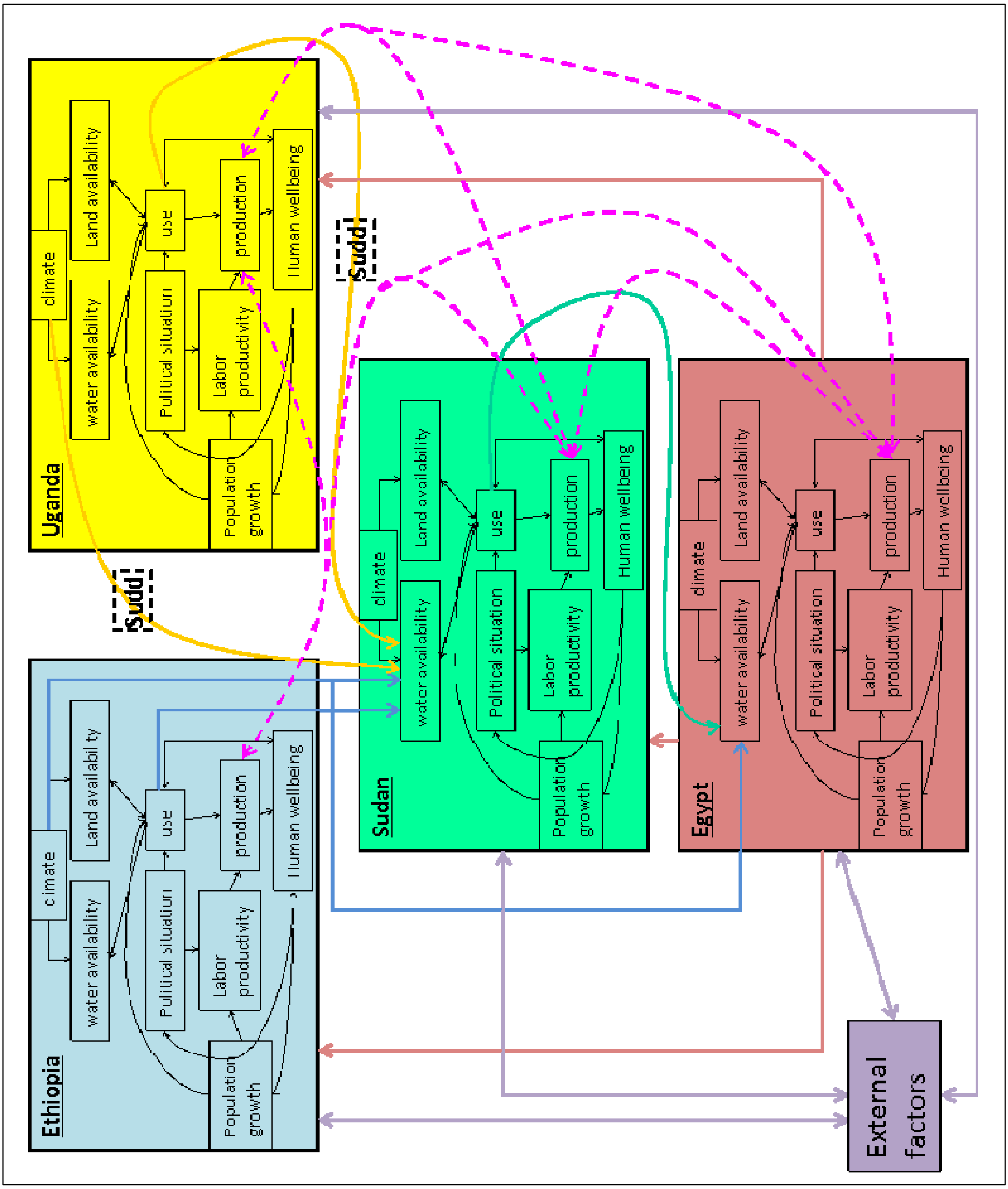


Figure 2.1: The impact graph illustrating the Nile Basin interactions which are further explained and analyzed in the text. The black arrows are intra-state interactions, the colored arrows interstate interactions, fitting the color of the country box they belong to. The dashed arrows stand for technical cooperation. The small dashed box "Sudd" indicates the Sudd swamps in South Sudan, where large amounts of water evaporate, reducing the importance of the White Nile for the downstream states.

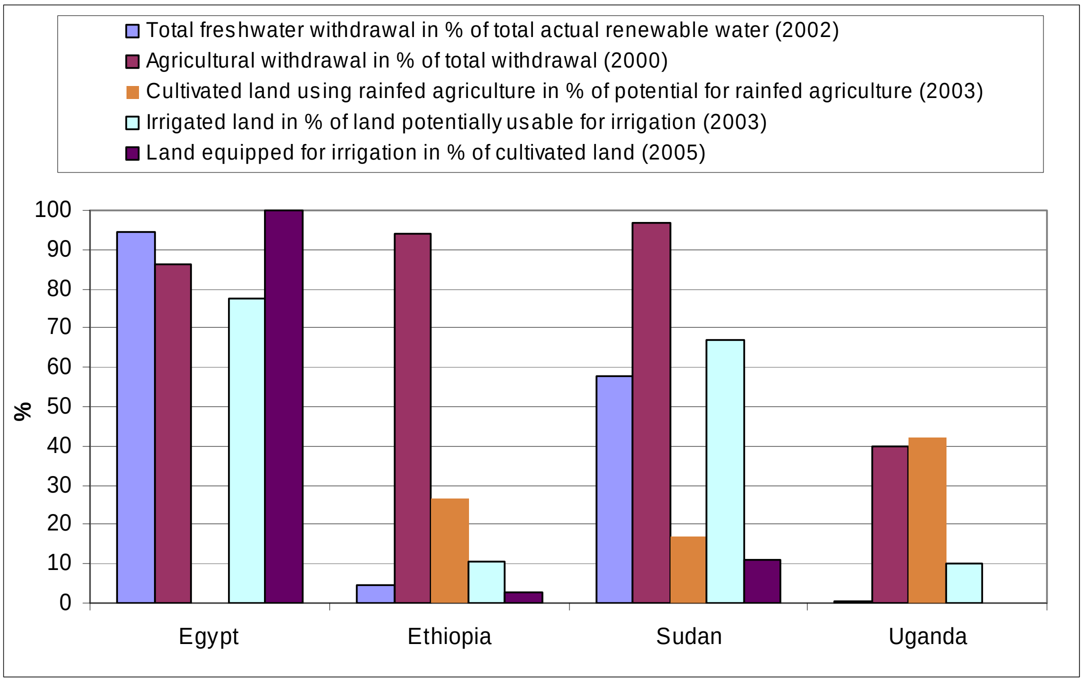


Figure 2.2: Use of land and water. The data for land equipped for irrigation are from different years (Egypt: 2002, Ethiopia: 2001, Sudan: 2000, Uganda: 1998), the 2005 relates to the year of the data for the total cultivated land. (Data sources: Aquastat 2010, The World Factbook 2010, Terrastat 2010).

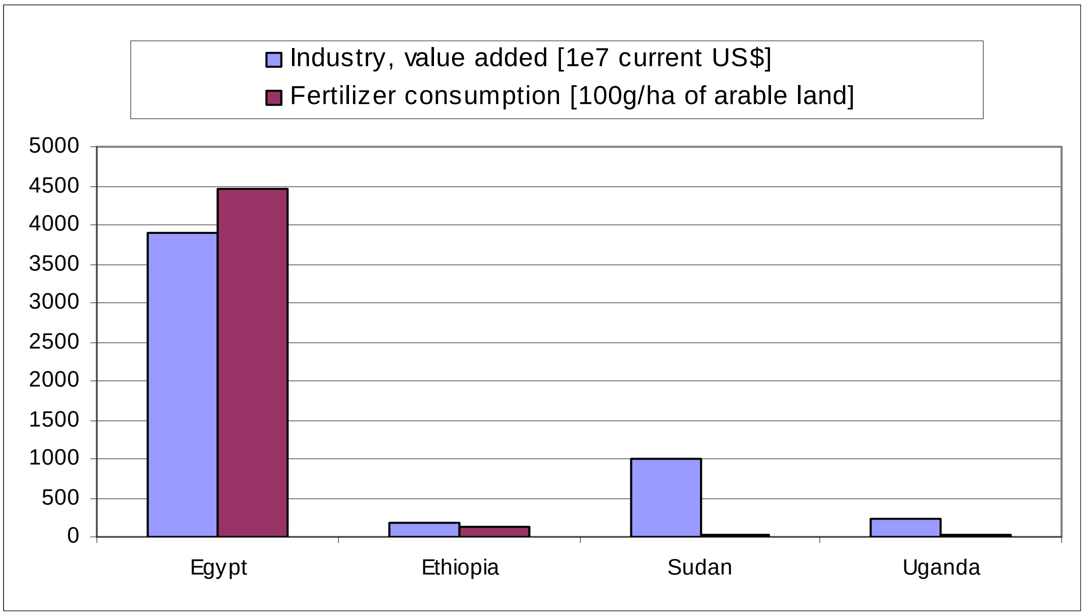


Figure 2.3: The main sources of pollution of the Nile (Data source: African Development Indicators 2010, data from 2006).

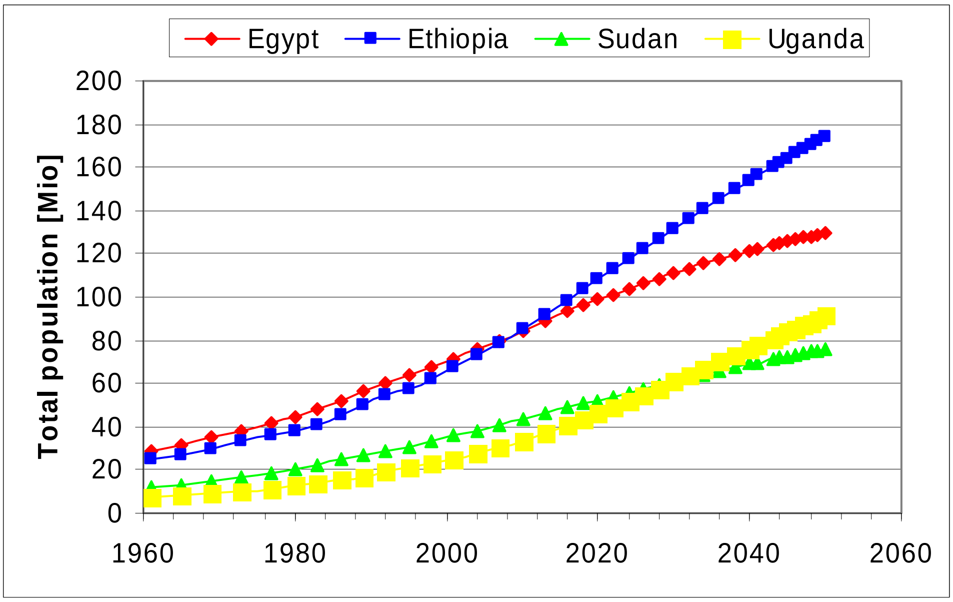


Figure 2.4: Population growth as one of the main shaping factors in the Nile Basin (Data source: World Population Prospects 2008).

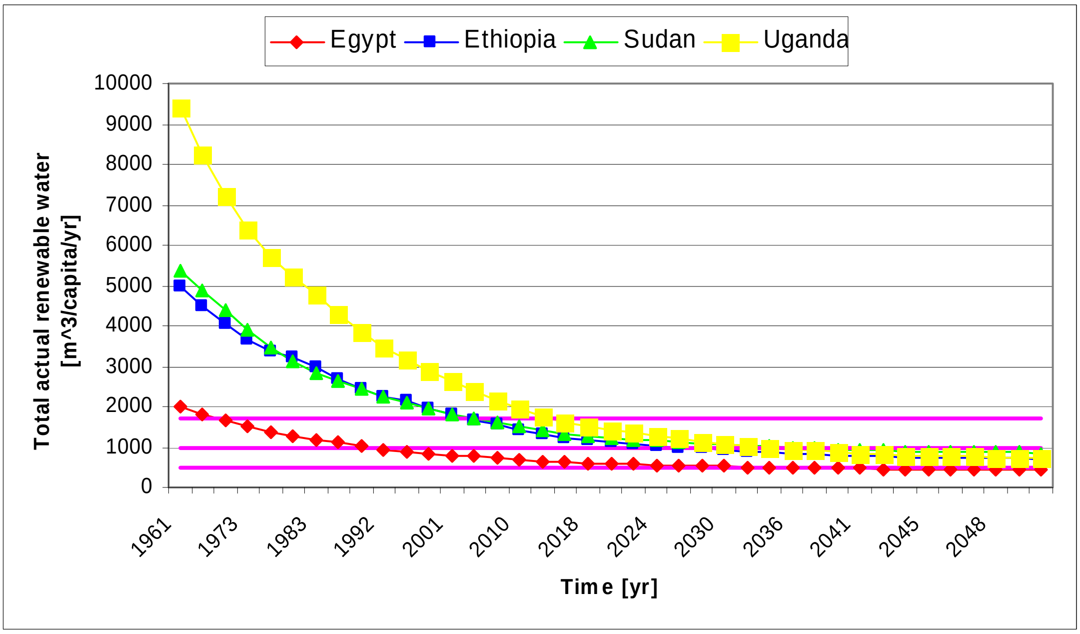


Figure 2.5: Expected increasing water stress in all Nile countries under the assumption of constant water availability. The pink lines indicate the Falkenmark thresholds for water scarcity (severe scarcity: < 500 m^3/capita/yr, scarcity: < 1000 m^3/capita/yr, stress: < 1700 m^3/capita/yr, Falkenmark et al. 1989). (Data sources: Aquastat 2010, World Population Prospects 2008).

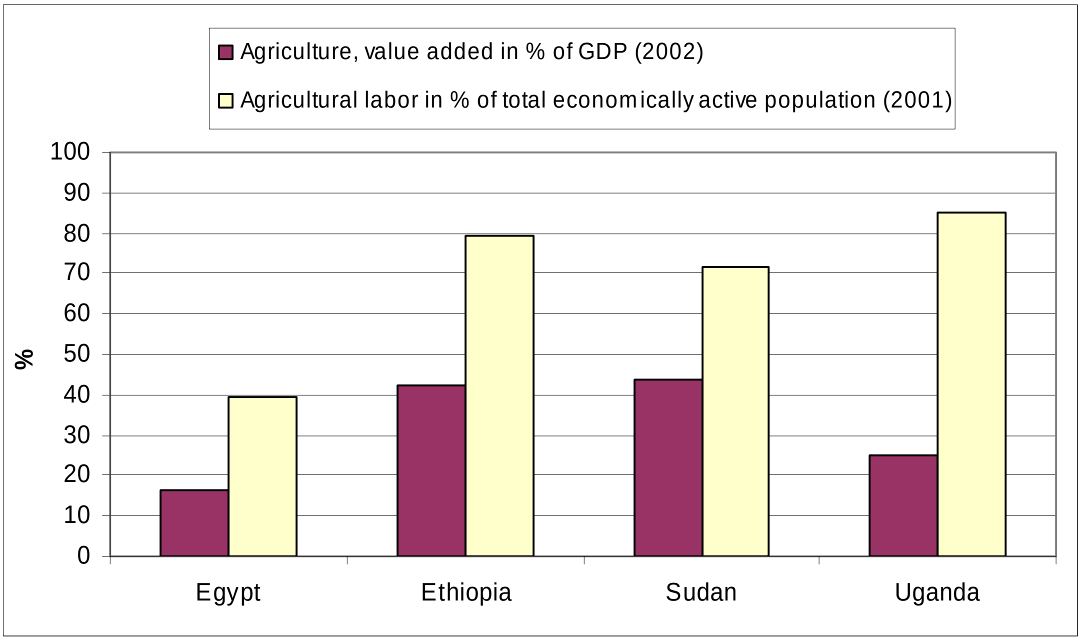


Figure 2.6: The importance of the agricultural sector (Data sources: Aquastat 2010, FAOstat 2010).

Table 2.1: Governance Indicators (2010, data from 2008). The definitions provided are taken from Kaufmann et al. (2009:6)

Indicator	Definition	Egypt	Ethiopia	Sudan	Uganda
Voice & account-ability	Capturing perceptions of the extent to which a country's citizens are able to participate in selecting their government as well as freedom of expression, freedom of association, and a free media.	14.4	10.6	4.3	33.2
Political stability	Capturing perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism	23	6.2	1.9	18.7
Government effectiveness	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	43.1	39.8	5.2	36
Regulatory quality	Capturing perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development	49.3	19.8	7.2	50.2
Rule of law	Capturing perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence	52.6	33.5	4.3	36.8
Control of corruption	Capturing perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.	29.5	30.4	2.4	23.2

Table 2.2: Indicators for labor productivity. The land area is provided for better assessment of the road network in comparison to the size of the country (Data source: EarthTrends 2010).

Country	Land area [km^2] (2010)	Total road network [km]	Vehicles per 1000 people	Literacy rate (all adults) [%]	Gross enrolment in secondary education [%]
Egypt	995,450	92,370 (2004)	29.7 (1996)	66.4 (2006)	88 (2004)
Ethiopia	10^6	36,469 (2004)	1.4 (1996)	35.9 (2007)	30 (2007)
Sudan	2,376,000	11,900 (2001)	10.4 (1996)	60.9 (2000)	33 (2007)
Uganda	197,100	70,746 (2003)	4.2 (1996)	73.6 (2007)	18 (2005)

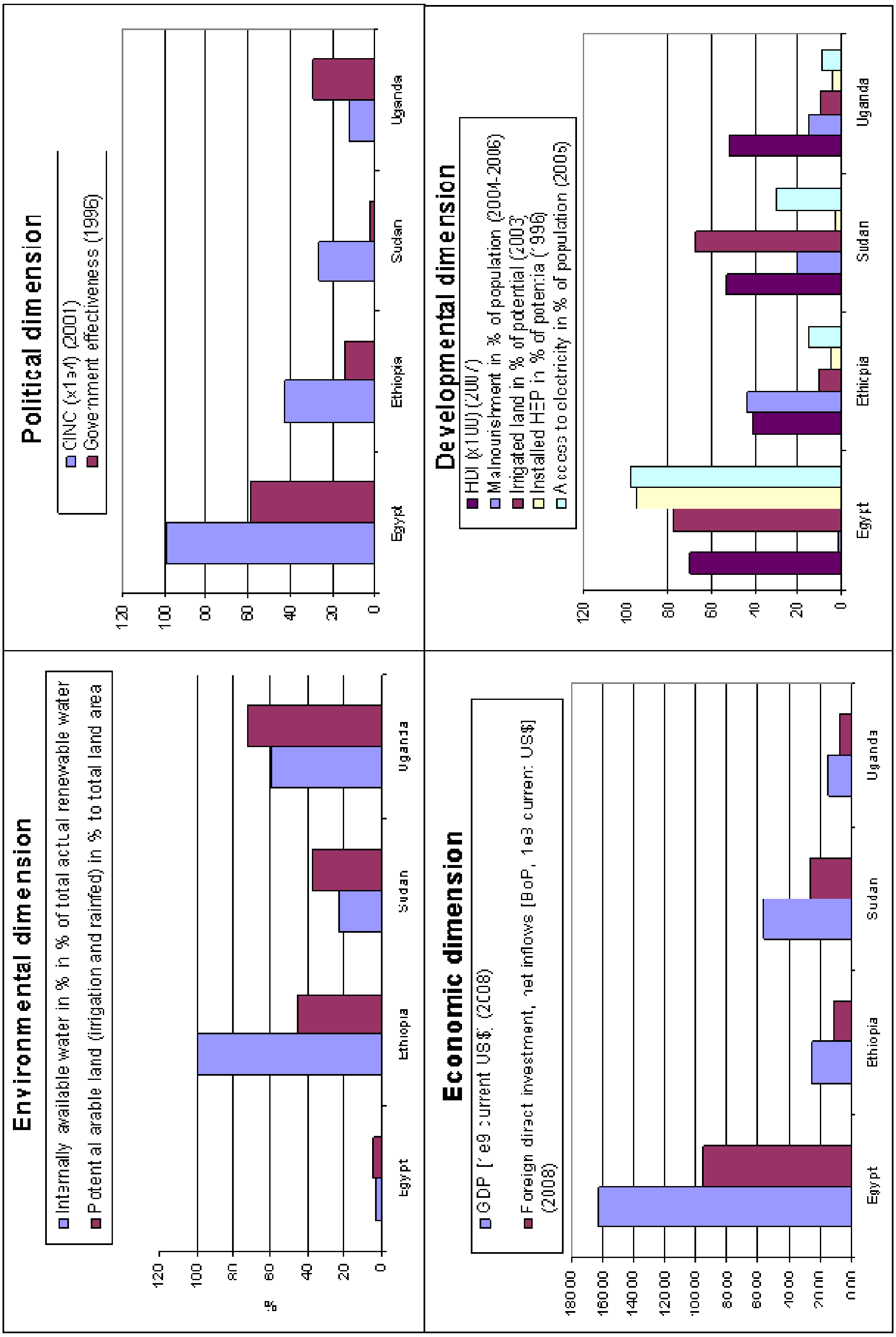


Figure 3.1: The four dimensions of Nile Basin asymmetries (Data sources: Amer et al. 2005, Aquastat 2010, The World Factbook 2010, Correlates of War 2010, EarthTrends 2010, FAOstat 2010, Gleick 1998, Kaufmann et al. 2009, Terrastat 2010, World Development Indicators 2009, Human Development Report 2009).

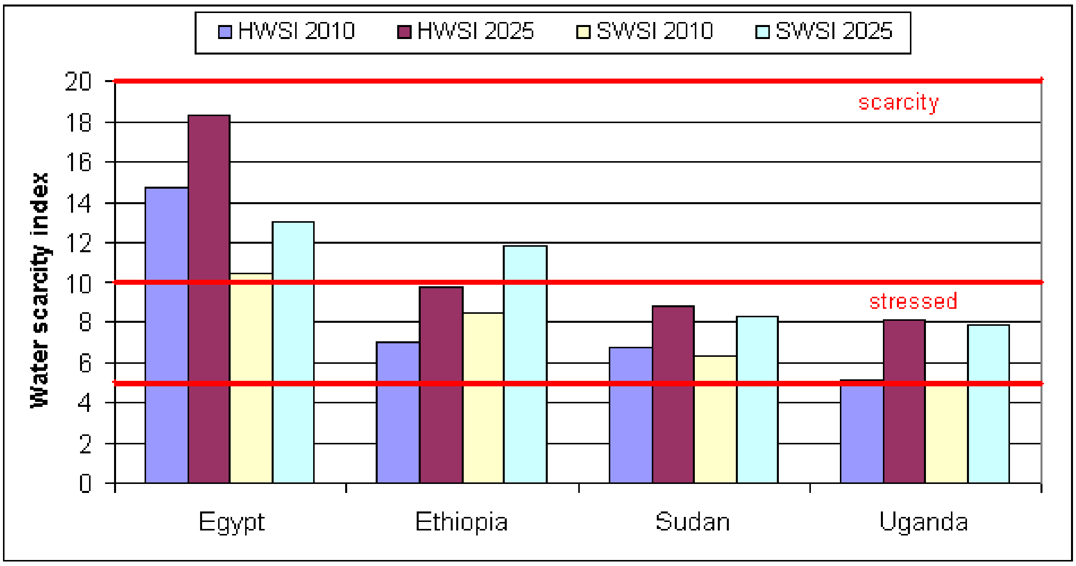


Figure 3.2: The comparison of hydrological water scarcity index (HWSI) and social water scarcity index (SWSI) indicates the importance of adaptive capacity. The red lines correspond to the Falkenmark definitions of water scarcity (see Figure 2.5). (Data sources: Aquastat 2010, Human Development Report 2009, World Population Prospects 2008).

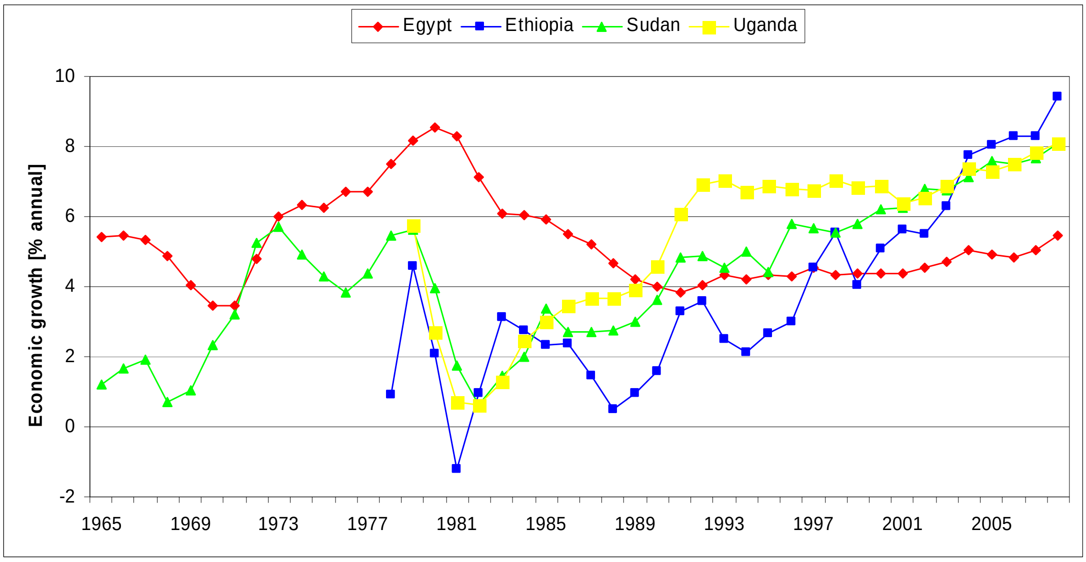


Figure 3.3: Annual economic growth in %, smoothed over 10 years (Data source: World Development Indicators 2009).

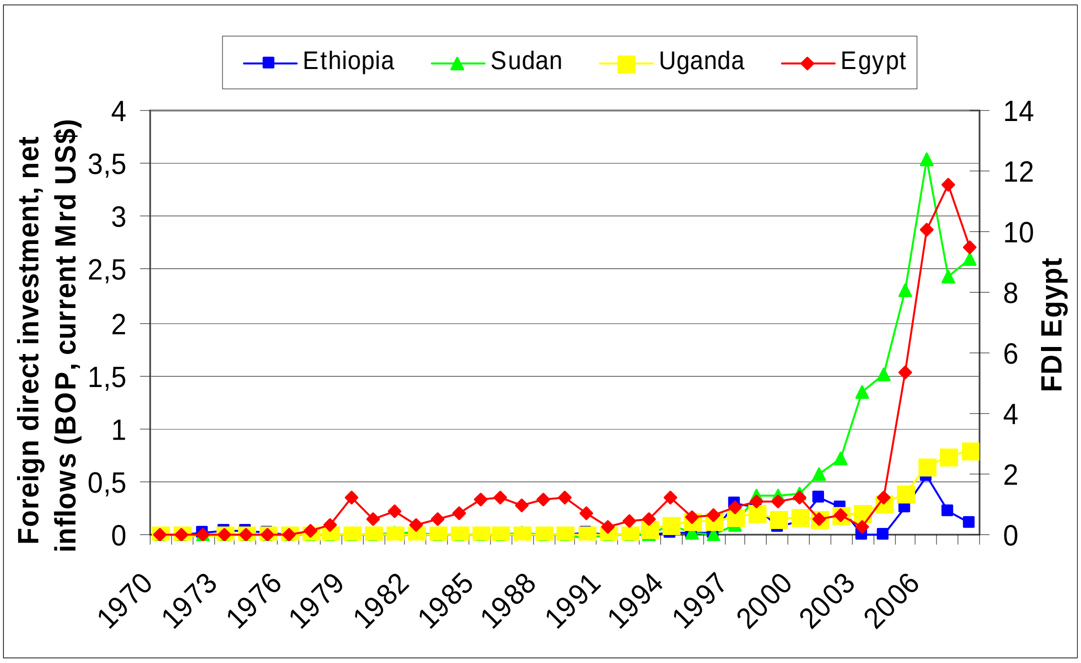


Figure 3.4: Foreign direct investment. The data for Egypt are shown on the right axis. (Data source: World Development Indicators 2009).

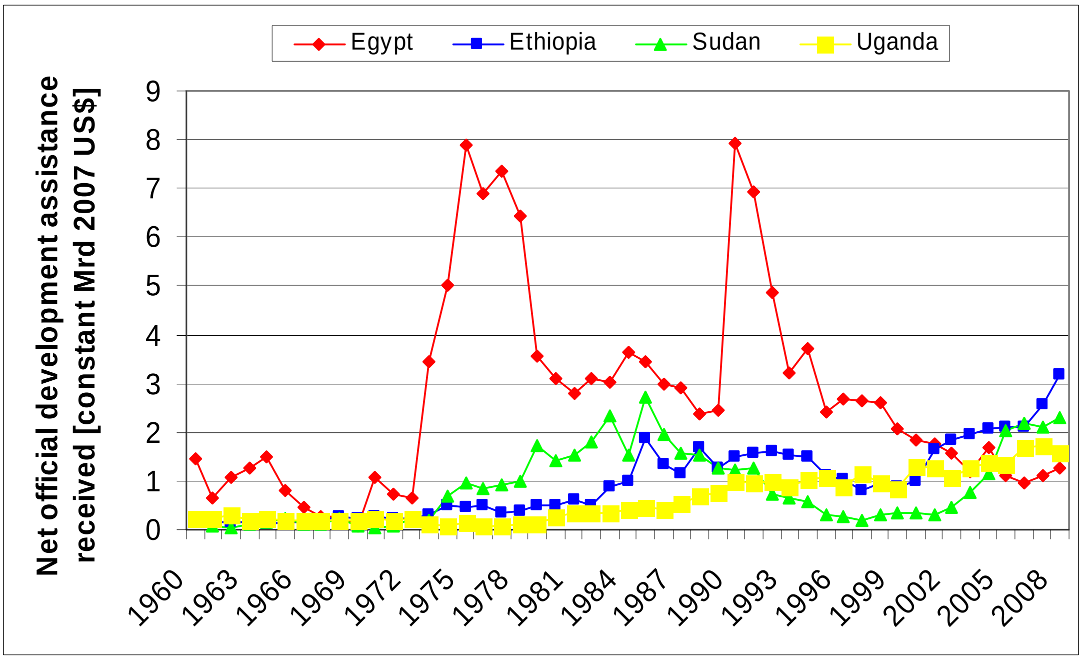


Figure 3.5: Net official development assistance (Data source: World Development Indicators 2009).

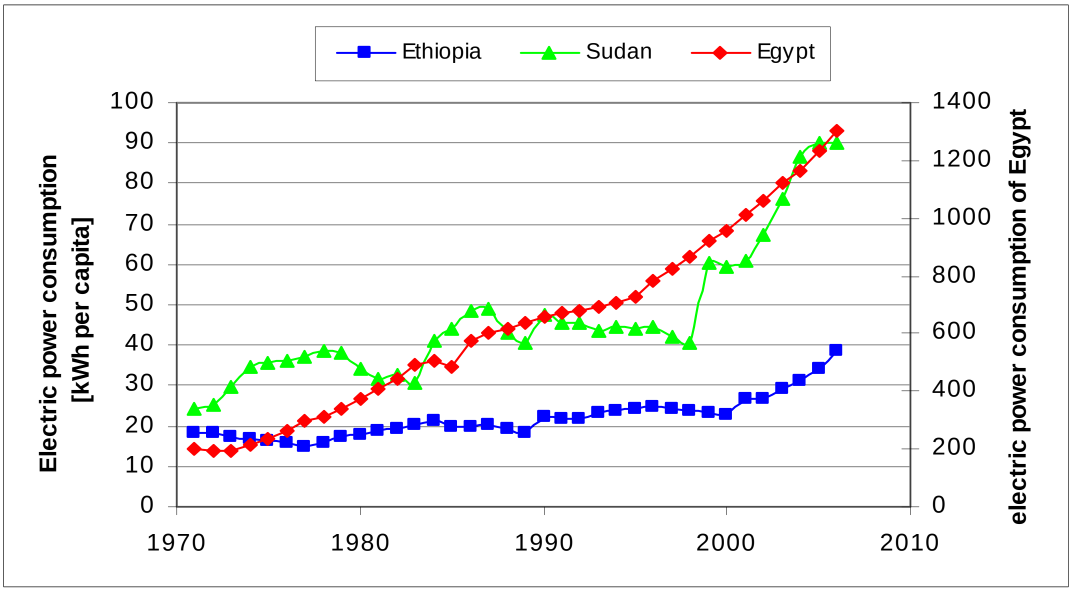


Figure 3.6: The increasing power consumption indicates economic development and a greater need for power. The data for Egypt are shown on the right axis. No data were available for Uganda. (Data source: African Development Indicators 2010)

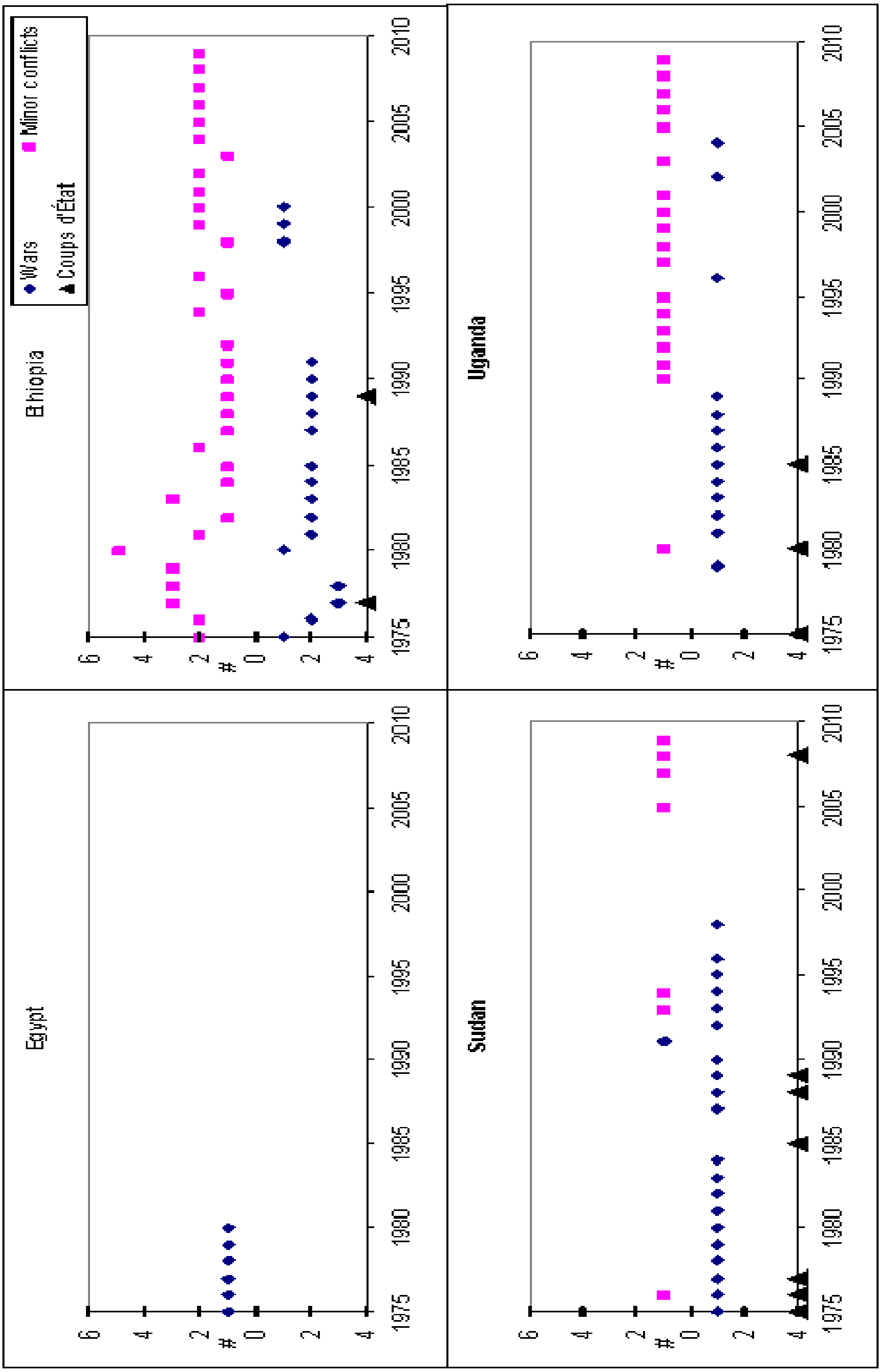


Figure 3.7: The number of wars, minor armed conflicts and coups d'état 1975 – 2009. The latter only includes successful and attempted coups. (Data source: Center for Systemic Peace 2010, Uppsala Conflict Data Program 2010).

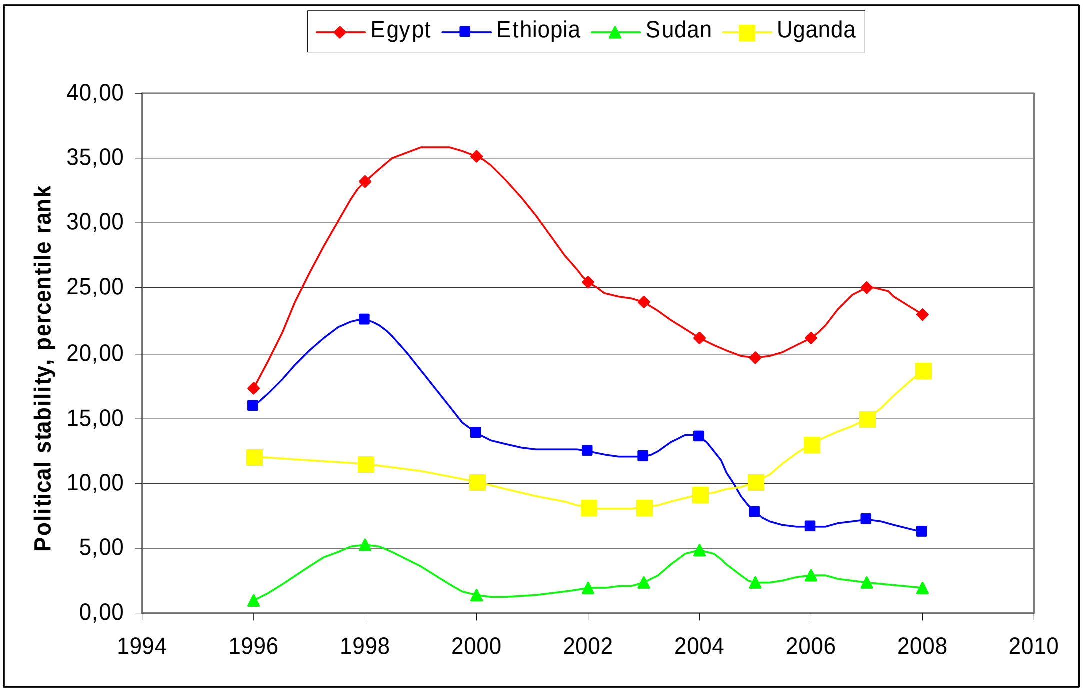


Figure 3.8: Political stability measured as percentile rank (Data source: Worldwide Governance Indicators 2010).

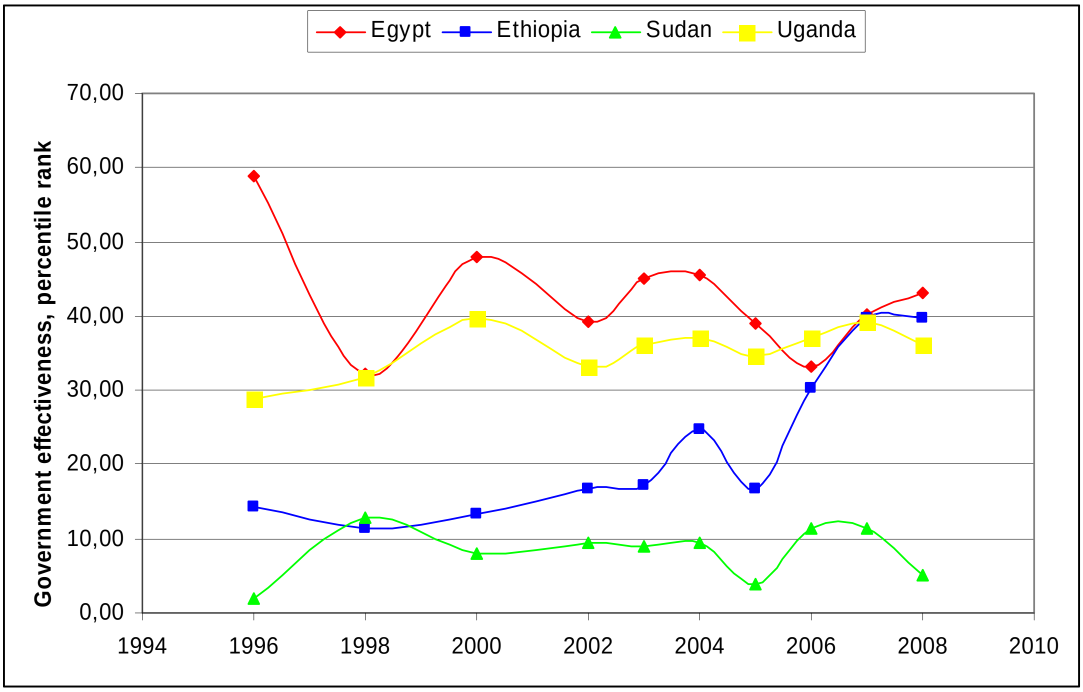


Figure 3.9: Government effectiveness measured as percentile rank (Data source: Worldwide Governance Indicators 2010).

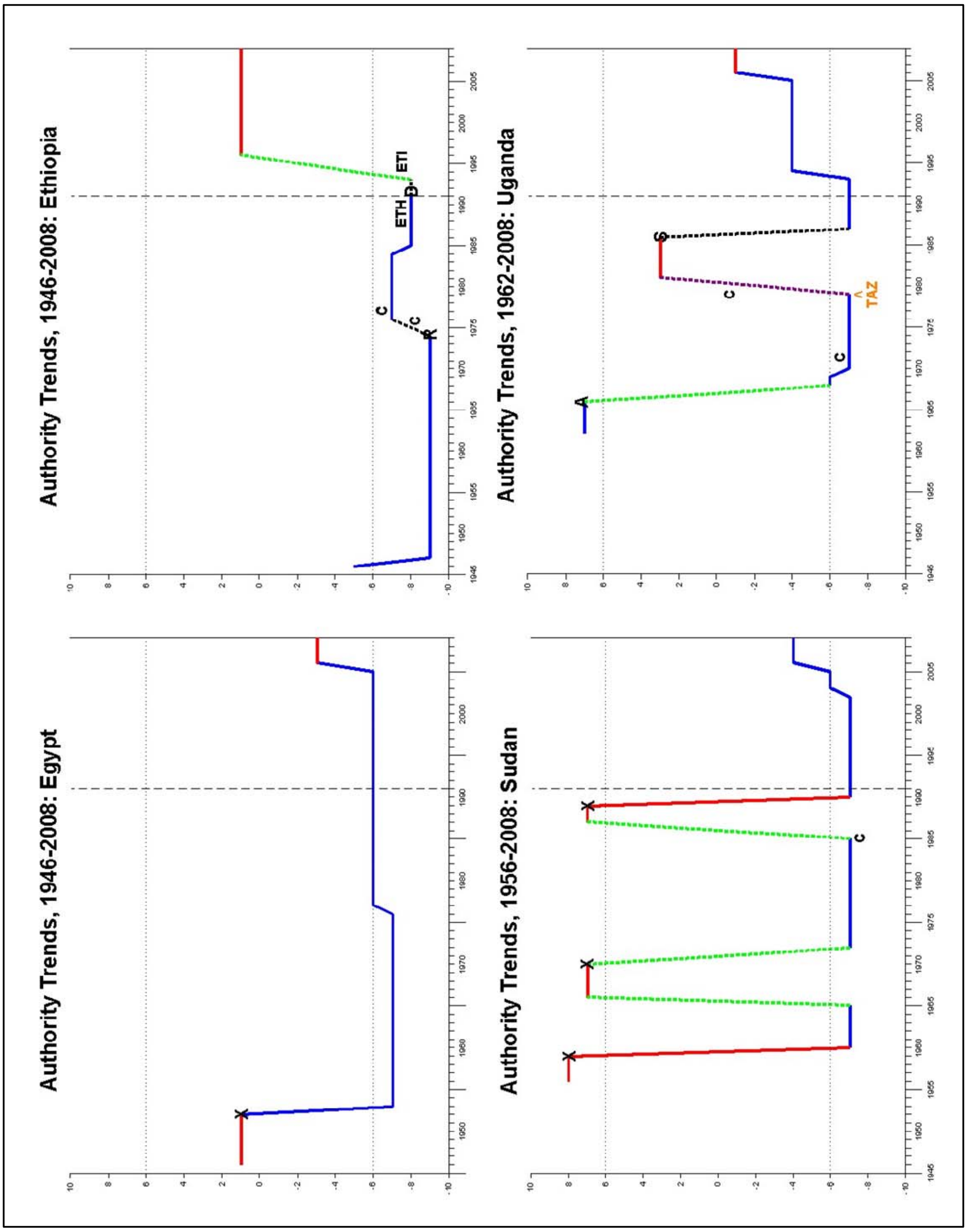


Figure 3.10: Polity scores. The horizontal dotted lines indicate the thresholds for autocracy (≤ -6) and democracy (≥6). The vertical dashed line indicates the end of the cold war in 1991. The different colors of the graph indicate special Polity conditions (red: factionalism, dashed purple: interruption, dashed black: interregnum, dashed green: transition), while the polity scores are shown by the blue line. The capital letters stand for Polity change events (X: autocratic back-sliding, A: executive auto-coups, R: revolutionary change, S: state failure, C: coup d'état). Bold orange carets stand for direct foreign military regime change intervention, with the intervening state indicated. For Ethiopia the independence of Eritrea is indicated by the D and shift from country code ETH to ETI in 1991. (Plots taken from Polity IV Individual Country Regime Trends, 1946-2008, Marshall and Jaggers 2008).

Table 3.1: Causal chain analysis of the Nile Basin interstate relations. The time periods are chosen so that important events mark the division – the 1959 agreement, the foundation of the NBI in 1999 and the opening of the CFA for signature in 2010. WEIS is the Water Event Intensity Scale as shown in Appendix B.

Time period	Root cause	Activities	Immediate cause	Conflict resolution capabilities	Issue: Conflict or cooperation	Type of hydro-hegemony
1959 – 1999	- Limited water resources - Asymmetries	- Hostile rhetoric - Egypt prevents upstream development of water resources	Egypt controlling 75% of the Nile waters		Conflict: securitized WEIS = -3 Cooperation: very limited	Dominant: Egypt dominates in all power dimensions & in exploitation potential
1999 – 2010	- Limited water resources - Asymmetries - Population pressure - Upstream need for development	- Unilateral actions (facts on the ground) - NBI - CFA negotiations	Upstream challenge to Egyptian hydro-hegemony	NBI D3 project	Conflict: securitized WEIS = -2 Cooperation: mainly technical	Openly contested: relative gain in upstream power & exploitation potential, use of bargaining power from upstream position
2010 - ?	- Limited water resources - Asymmetries - Population pressure - Upstream need for development	- Unilateral actions (facts on the ground) - NBI - CFA negotiations	Upstream states opening CFA for signature	NBI Expressed wish for cooperation	Conflict: securitized WEIS = -3 Cooperation: unclear	

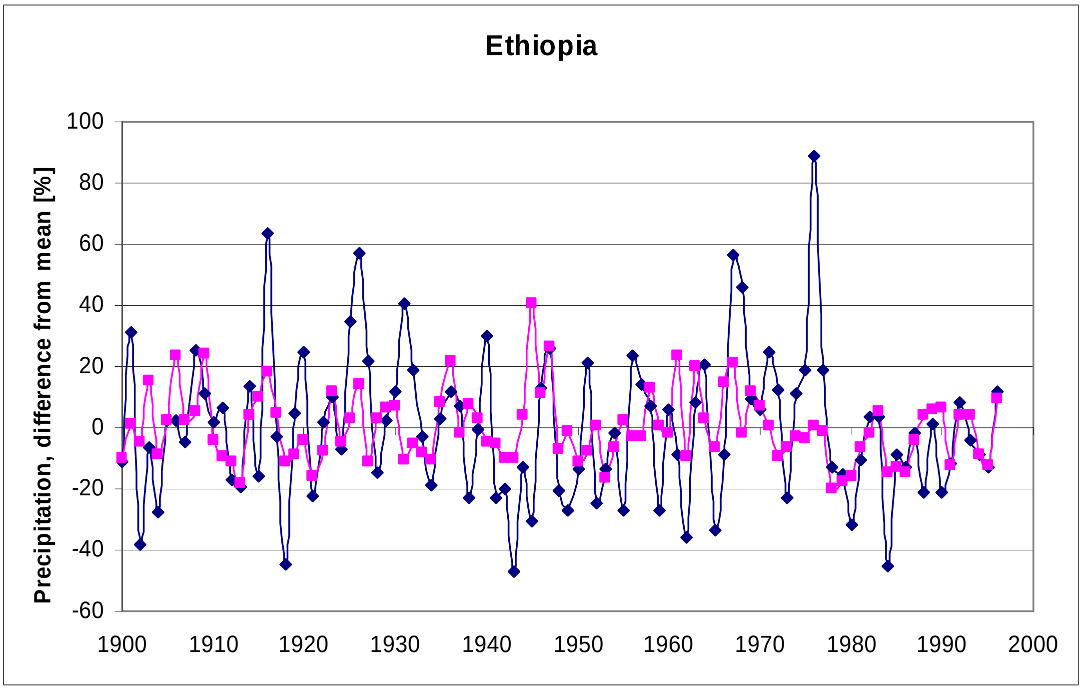


Figure 4.1: Long-term precipitation trends for Ethiopia. The different colors indicate two different measuring stations. The high variability and lack of a trend are visibile. (Data source: Climate Research Unit 2010).

Table 4.1: Natural disaster statistics for the period from 1970-2010. The data for Egypt do not include earthquakes. (Data source: EM-DAT 2010).

	# of events	# of people affected (Mio)	# of people killed (Thousands)	# of people homeless (Thousands)	Economic damage (Mio US$)	Most common type of event
Egypt	21	0.19	0.99	54	156	Floods, storms, extreme temperatures
Ethiopia	88	54	414	195	107.7	Floods, epidemics, droughts
Sudan	78	32.2	160.7	1440	551.2	Epidemics, floods, droughts
Uganda	62	4.77	2.28	320	72.7	Epidemics, floods, droughts

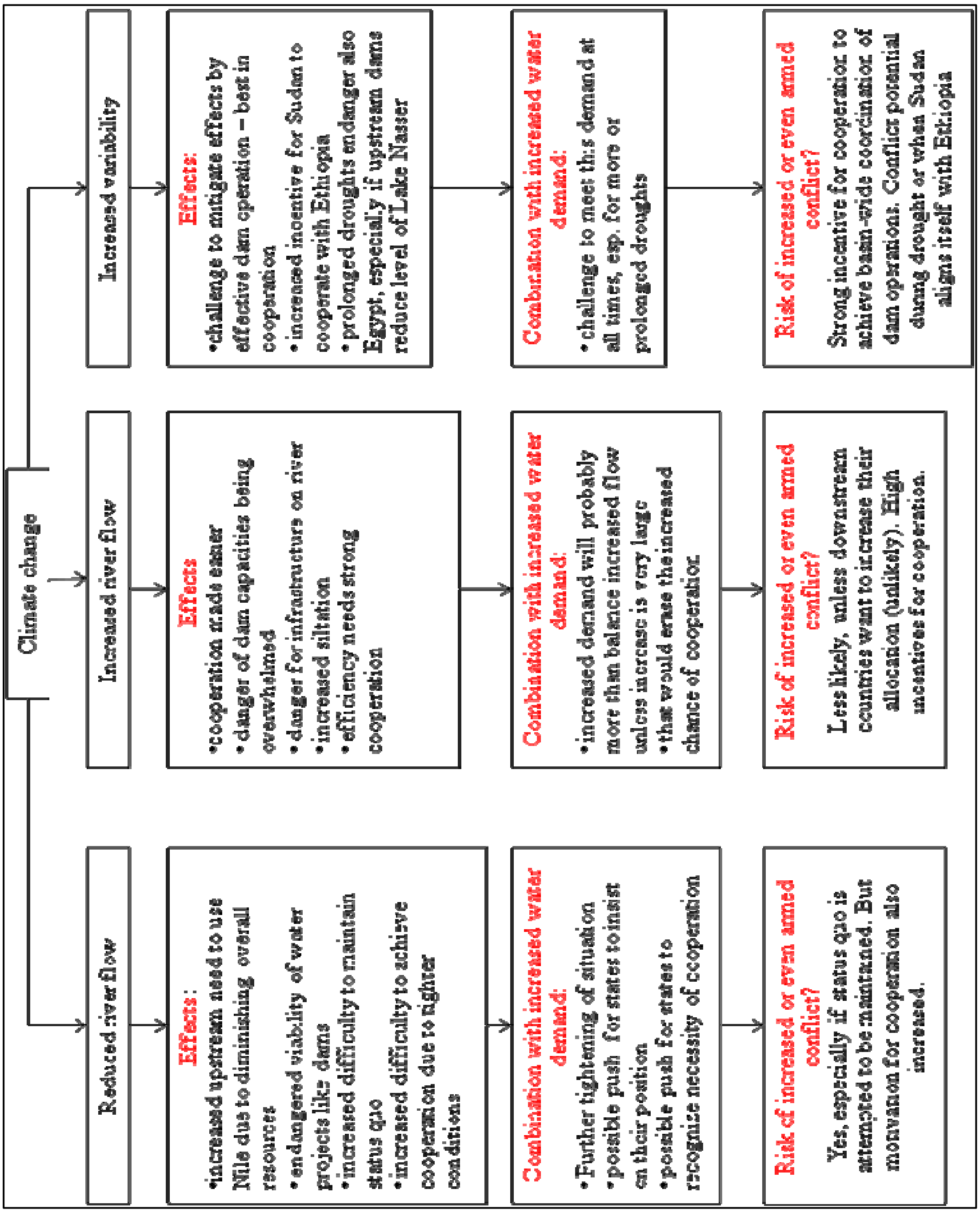


Figure 5.1: An overview of the effects of climate change on water supply and the link to the occurrence of conflict or cooperation, taking into account the likely increase in water demand due to climate change, population growth and development. This is described in Sections 5.1.1 and 5.1.2.

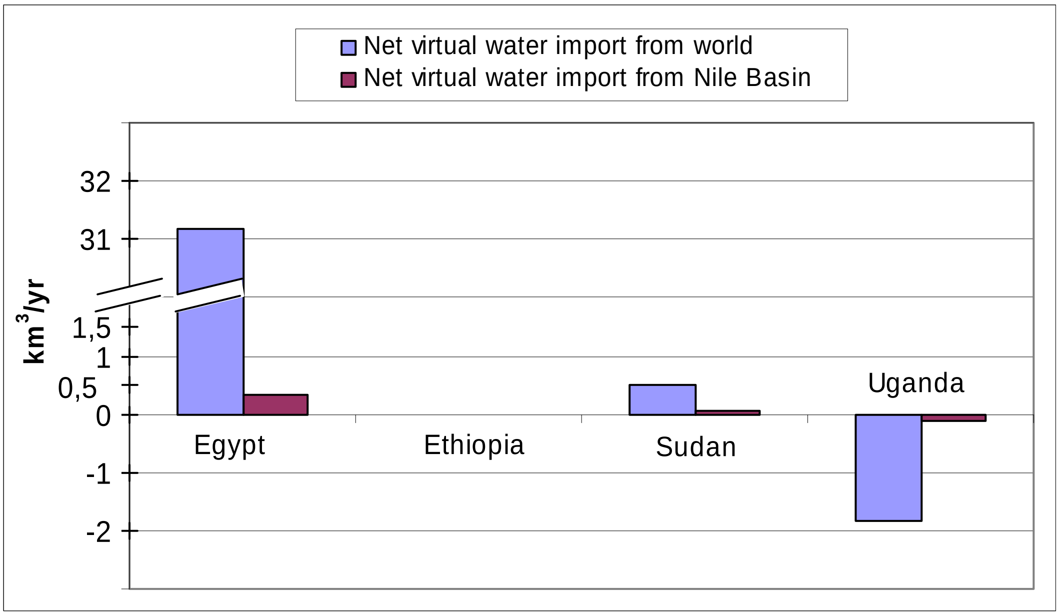


Figure 5.2: Virtual water trading as a way to address water scarcity (Data source: Allan 2009).

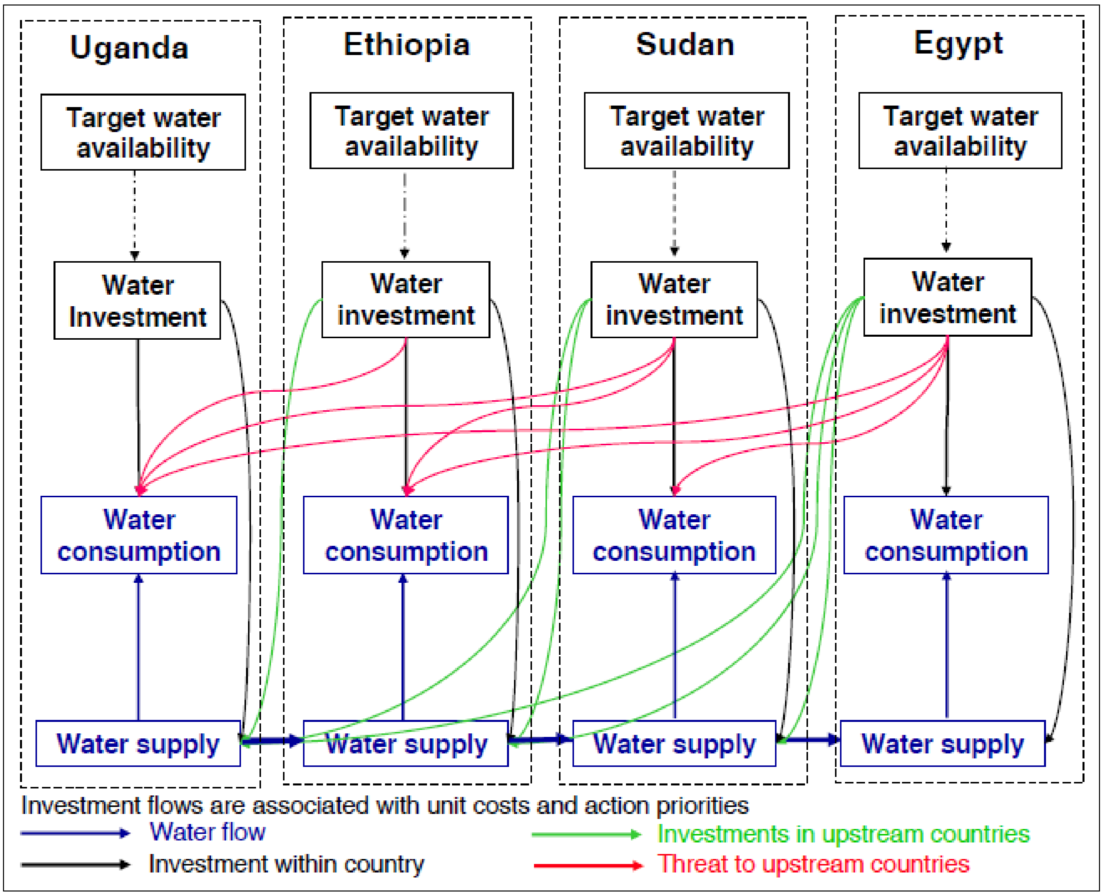


Figure 5.3: Structure of the agent-based model (taken from Link et al. 2010).

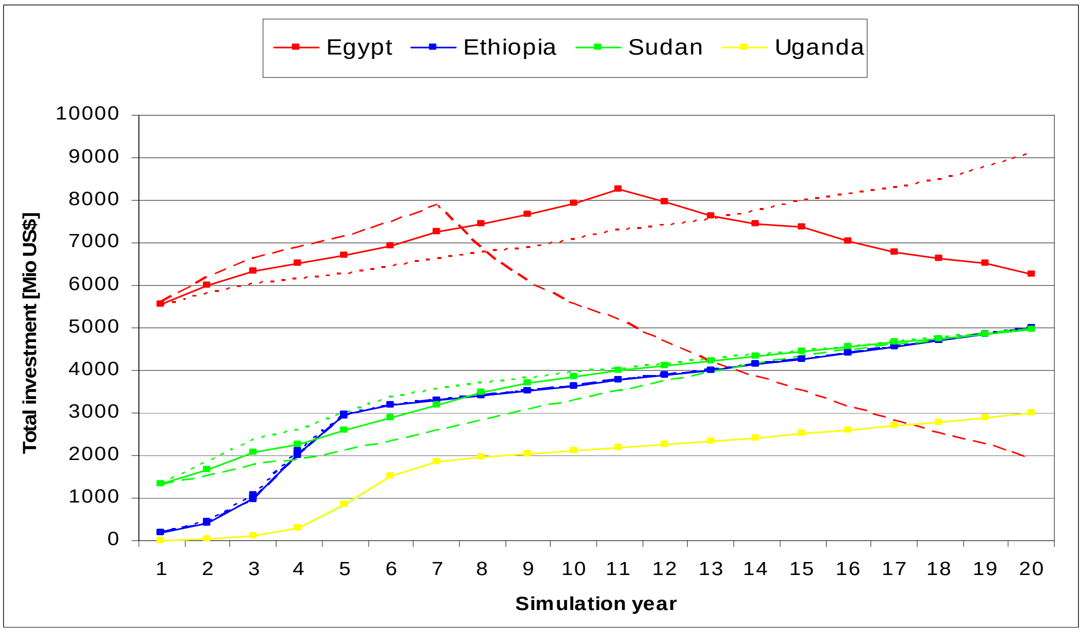


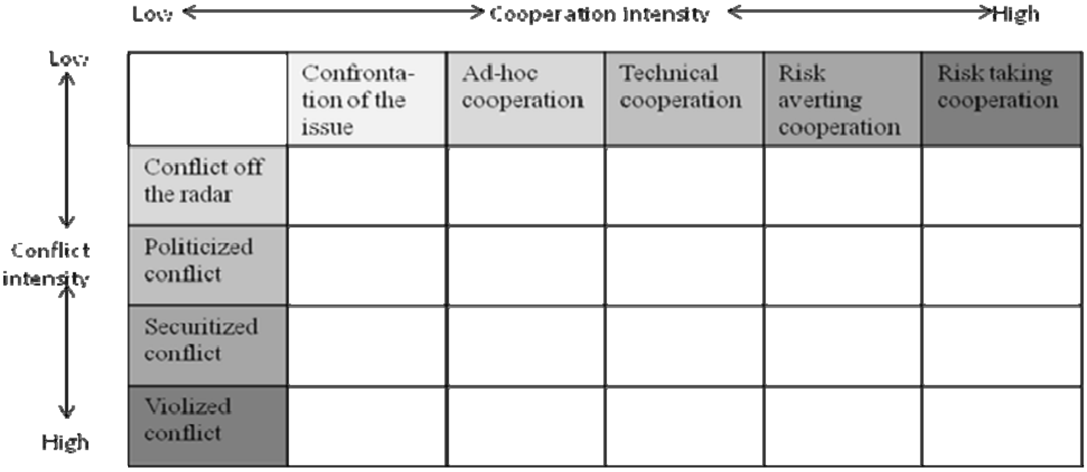
Figure 5.4: Exemplary results from the agent-based model for total investments with the goal to keep the per capita water consumption constant (Egypt) and increase it to 500 m³/yr (Sudan, Ethiopia, Sudan) over the simulation time. The solid line with the symbols is the baseline model, the long-dashed line is the positive climate change scenario (+20% water), the short-dashed line is the negative climate change scenario (-20% water).

Appendix B: Rating Systems for Transboundary Water Conflicts: WEIS & TWINS

The Water Event Intensity Scale (WEIS), taken from Zeitoun and Warner (2006) (who quote Yoffe 2001):

Scale	Event description
7	Voluntary unification into one nation
6	Major strategic alliance (International Freshwater Treaty)
5	Military, economic or strategic support
4	Non-military economic, technological or industrial agreement
3	Cultural or scientific support (non-strategic)
2	Official verbal support of goals, values, or regime
1	Minor official exchanges, talks or policy expressions – mild verbal support
0	Neutral or non-significant acts for the inter-nation situation
-1	Mild verbal expressions displaying discord in interaction
-2	Strong verbal expressions displaying hostility in interaction
-3	Diplomatic – economic hostile actions
-4	Political – military hostile actions
-5	Small scale military acts
-6	Extensive war acts causing deaths, dislocation or high strategic costs
-7	Formal declaration of war

The Transboundary Water Interaction Nexus (TWINS, Mirumachi 2006) as shown in Zeitoun and Mirumachi (2008):



Appendix C: A List of Data Collected for the Empirical Analysis

Category	Variable	Source
Climate	Mean annual temperatures	Aquastat (2010) (Country Profiles)
	Average annual rainfall	Aquastat (2010) (Country Profiles)
	Long-term precipitation trends	Climate Research Unit (2010)
	Climate change trends	Various sources, see text
	Natural disaster statistics	EM-DAT (2010)
Land availability	Total land area	EarthTrends (2010)
	Potentially cultivatable land, rainfed agriculture	Terrastat (2010)
	Potentially cultivatable land, irrigated agriculture	Aquastat (2010)
	Land erosion/degradation	Terrastat (2010)
Water availability	Total renewable water resources (groundwater & surface water, external & internal, inflow & outflow, dependence ratio)	Aquastat (2010)
	Amount of desalinated water	Aquastat (2010)
	Amount of treated wastewater	Aquastat (2010)
	Virtual water export (within basin and worldwide)	Allan (2009)
Use	Cultivated land, rainfed agriculture	The World Factbook (2010)
	Cultivated land, irrigated agriculture	The World Factbook (2010)
	Land equipped for irrigation	Aquastat (2010)
	Soil water consumption	Allan (2009)
	Water withdrawal (total and by sector)	Aquastat (2010)
	Installed HEP	Gleick (1998)
	Potential for HEP	Amer et al. (2005)
Population growth	Population, projections	World Population Prospects (2008)
	Growth rates	FAOstat (2010)
	Urban/rural population	FAOstat (2010)
Political situation	Wars/minor armed conflicts	Uppsala Conflict Data Program (2010)
	Coups d'état	Center for Systemic Peace (2010)
	Worldwide Governance Indicators	Worldwide Governance Indicators (2010)
	Polity Scores	Center for Systemic Peace (2010) (see Marshall and Jaggers 2008)
	Composite Index of National Capabilities (CINC)	Correlates of War (2010) (see Singer 1987)

Labor productivity	Fraction of population aged 0-14	World Development Indicators (2009)
	Unemployment rates	The World Factbook (2010)
	Economically active population (total and in agriculture)	FAOstat (2010)
	Total road network	EarthTrends (2010)
	Vehicles per 1000 people	EarthTrends (2010)
	Literacy rate	EarthTrends (2010)
	Gross enrolment in secondary education	EarthTrends (2010)
Production	GDP	World Development Indicators (2009)
	Foreign direct investment	World Development Indicators (2009)
	Economic growth rates	World Development Indicators (2009)
	Net official development assistance	World Development Indicators (2009)
	Agriculture contribution to GDP, value added	Aquastat (2010)
	Industry contribution to GDP, value added	African Development Indicators (2010)
	Fertilizer consumption	African Development Indicators (2010)
	Electric power consumption	African Development Indicators (2010)
Human wellbeing	Human Development Index	Human Development Report (2009)
	Access to an improved source of sanitation	EarthTrends (2010)
	Access to electricity	EarthTrends (2010)
	Malnourishment	FAOstat (2010)

Appendix D: An Overview of Relevant Agreements

This information is based on the International Freshwater Treaty Database (Wolf 2010) and Hefny and Amer (2005). Only agreements related to water are included.

Name	Date	Information
Protocol between Great Britain and Italy for the demarcation of their respective spheres of influence in Eastern Africa	April 15 1891	Italy agrees to refrain from any irrigation or other projects on the Atbara river which could affect its flow into the Nile
Exchange of notes between Great Britain and Ethiopia	March 18 1902	Ethiopia agrees to refrain from any projects on the Blue Nile, Lake Tana or the Sobat river which could affect the flow of the Nile unless under an agreement with Sudan and Egypt
Agreement between Great Britain and the Independent State of the Congo, modifying the agreement signed at Brussels, 12 May 1894, relating to the spheres of influence of Great Britain and the Independent State of the Congo in East and Central Africa	May 9 1906	Congo agrees to refrain from projects affecting the flow of tributaries to Lake Albert without consulting Sudan For full text see http://ocid.nacse.org/tfdd/tfdddocs/40ENG.pdf
Agreement between Great Britain, France, and Italy respecting Abyssinia	December 13 1906	The signatories agree that, in case of problems in the region, the rights of Egypt and the United Kingdom to the Nile waters should be protected, especially with respect to water regulation in the Nile and its tributaries For full text see http://ocid.nacse.org/tfdd/tfdddocs/43FRE.pdf
Exchange of notes between the United Kingdom and Italy respecting concessions for a barrage at Lake Tana and a railway across Abyssinia from Eritrea to Italian Somaliland	December 20 1925	- construction of a reservoir at Lake Tana - Italy recognizes prior rights of Egypt and Sudan to the Nile waters and agrees to refrain from projects in the headwaters region affecting Nile flow - right of local inhabitants to construct small dams and reservoirs on secondary branches
Exchange of notes between His Majesty's government in the United Kingdom and the Egyptian Government in regard to the use of the waters of the River Nile for irrigation purposes	May 7 1929	- No projects reducing the amount of water reaching Egypt on Nile, its tributaries and lakes - Egypt has right to inspect projects - Egypt has right to explore Nile and its tributaries - Egypt's historic rights to the Nile are recognized - allocation of 48 km^3/yr to Egypt and 4 km^3/yr to Sudan For full text see http://ocid.nacse.org/tfdd/tfdddocs/92ENG.pdf
Agreement between the United Kingdom and Belgium regarding water rights on the boundary between Tanganyika and Ruanda-Burundi	November 22 1934	Agreement regarding the use of the Kagera river for HEP For full text see http://ocid.nacse.org/tfdd/tfdddocs/110ENG.pdf
Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and	January 5 1953 (plus preparation	- Allows for construction of the Owen Falls Dam north of Lake Victoria - lake is storage and flow control reservoir - the amount or timing of water arriving in Egypt

Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam in Uganda	agreements from May 31 1949, December 5 1949, March 20 1950)	should not be affected - Egyptian engineers at the site operate the reservoir For full text see http://ocid.nacse.org/tfdd/tfdddocs/169ENG.pdf
Agreement between the government of the United Arab Republic and the government of Sudan for full utilization of the Nile waters	November 8 1959	- reallocation compared to 1929 agreement because of construction of Aswan High Dam: 55.5 km^3/yr to Egypt, 18.5 km^3/yr to Sudan (84 km^3/yr total flow, 10 km^3/yr evaporation over Lake Nasser) - construction of Roseires reservoir in Sudan - Permanent Joint Technical Commission - joint position towards other states - review procedure in case of flow changes (equal sharing of reductions, benefitting other riparians) - start of projects to reduce evaporation losses in swamps (Jonglei canal) For full text see http://ocid.nacse.org/tfdd/tfdddocs/230ENG.pdf
Agreement for the establishment of the organization for the management and development of the Kagera river basin	August 24 1977 plus follow-up agreement on May 18 1981	- agreement between Burundi, Rwanda, Tanzania, Uganda forming an organization for joint river basin management and development - unclear if it ever entered into force
Exchange of letters between the Arab Republic of Egypt and Uganda on the Owen Falls Dam	May 1991	- reaffirming agreement from 1953 - expansion of the hydro-power plant - if needed Uganda is allowed to regulate flow without harming downstream countries (flow margins are set)
Framework for general cooperation between the Arab Republic of Egypt and Ethiopia	July 1 1993	- no projects on the Nile harming the other country - protection of Nile - compliance with international laws - consultation and cooperation with goal of increased flows and reduced losses For full text see http://ocid.nacse.org/tfdd/tfdddocs/521ENG.pdf
Convention for the establishment of the Lake Victoria Fisheries Organization (Kenya, Tanzania, Uganda)	June 30 1994	
Agreement to initiate program to strengthen regional coordination in management of resources of Lake Victoria (Kenya, Tanzania, Uganda)	August 5 1994	Initiation of a 5 year program for the coordination of the integrated management of Lake Victoria For full text see http://ocid.nacse.org/tfdd/tfdddocs/534ENG.pdf
Nile River Basin Cooperative Framework Agreement	May 14 2010	- draft for a basin-wide agreement was opened for signature for period of 1 year - signatories so far Ethiopia, Rwanda, Tanzania, Uganda, Kenya - content not publically available – reallocation of water, transformation of NBI into permanent Nile River Basin Commission

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Curriculum Vitae

Personal Details

Name:	Franziska Piontek (neé Köckert)
E-mail:	fpiontek@gmail.com
Date of Birth:	January 16 1980
Place of Birth:	Schleiz, Germany
Nationality:	German

Education

10/2009 – 08/2010	Master program "Master of Peace and Security Studies", Hamburg University, Germany
09/2005 – 09/2009	Astrophysical Institute Potsdam, Germany Degree: Ph.D., Physics (Magna cum laude) Thesis topic: The formation of disk galaxies: A systematic study"
08/2002 – 07/2005	University of Maryland, USA Degree: Master of Science, Astronomy (GPA 3.77)
10/1999 – 07/2002	Eberhard-Karls-Universität Tübingen, Germany Degree: Pre-Diploma, Physics (grade: "very good")
09/1992 – 07/1998	Kreisgymnasium Freital-Deuben, Germany Degree: Abitur (final grade: 1.3)

Awards

Scholarship of the German-American Fulbright Commission, 2002-2003

Languages

German	native speaker	English	fluent
French	basic		

Teaching and Research Experience

08/2003– 02/2006	Teaching Assistant, Department of Astronomy, University of Maryland, USA and Potsdam University, Germany
02/2002 – 07/2005	Research Assistant, Department of Astronomy, Tübingen University, Germany and University of Maryland, USA

Publications

Link, M., Piontek, F., Scheffran, J., Schilling, J. 2010. *Integrated Assessment of Climate Security Hot Spots in the Mediterranean Region: Potential Water Conflicts in the Nile River Basin.* Working Paper CLISEC-0003, presented at the conference *Climate Change and Security*, June 21-24 2010, Trondheim, Norway

Piontek, F. & Steinmetz, M. 2010. *The angular momentum problem in cosmological simulations of disk galaxy formation & The modeling of feedback processes in cosmological simulations of disk galaxy formation.* Submitted to Monthly Notices of the Royal Astronomical Society

Köckert, F., & Steinmetz, M. 2007. *Simulating disk galaxies: First results of a systematical study.* IAUS, 235, 114K

Köckert, F. & Reynolds, C.R. 2006. *On the detectability of X-ray absorption lines from the intracluster medium of galaxy clusters.* Monthly Notices of the Royal Astronomical Society, 368, 668

Honor Statement

I pledge that this Masters Thesis, entitled "The Impact of Climate Change on Conflict and Cooperation in the Nile Basin" has not been submitted for academic credit in any other capacity, and that this Masters Thesis has not yet been published.
I further pledge that I have written this Masters Thesis myself, on my own. I have not employed any sources or aids other than those listed. I have appropriately identified and acknowledged all words and ideas taken from other work.

Hamburg, den Franziska Piontek