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Integrated Assessment of Climate Security Hot Spots in the Mediterranean Region: Potential Water Conflicts in the Nile River Basin

University of Hamburg
Research Group Climate Change and Security

Working Paper
CLISEC-6

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Acknowledgement: Research for this paper was supported through the Cluster of Excellence 'CliSAP' (EXC177), University of Hamburg, which is funded through the German Science Foundation (DFG).

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

Abstract: To enhance the understanding of potential security risks posed by climate change, a framework for integrated assessment of climate security hot spots in the Mediterranean region is developed, with the Nile river basin as a case study. It is expected that the Mediterranean region will be severely affected by global warming. Rising temperatures and changing precipitation patterns exacerbate existing problems of desertification, water scarcity, and food production. Spillover effects (migration, ethnic links, resource flows, and arms exports) could expand the geographical extent of a crisis. The aim of this assessment is to identify the key links between climate change and security and their potential for inducing resource conflicts and societal instabilities. Based on data of key countries in the Nile River Basin regarding various economic, environmental, developmental, and political dimensions, an analysis of the potential regional security implications and conflicts is conducted. A system framework is introduced to outline the complex interactions between the most important variables of the climate system and fundamental socio-economic quantities in the upstream and downstream countries of this region. The computational modeling environment is used to assess the dynamic interactions between countries which invest into different action paths to improve water availability. Recent developments and different scenarios are discussed, alternative strategies and cooperative approaches are considered that enhance conflict prevention and governance structures to address security risks.

1 Introduction

Changes in climatic conditions have considerable impacts on societal stability and can increase resource scarcity, which in turn can increase the likelihood of violent conflict in various ways (Campbell et al., 2007; CNA, 2007; Maas and Tänzler, 2009; WBGU, 2008). The interconnections between environmental conditions, resource scarcity, individual anthropogenic wellbeing and possible societal instability are complex and difficult to assess quantitatively. Previous research on the link between climate change and conflict has so far been inconclusive (Barnett, 2003; Barnett and Adger, 2007; Nordås and Gleditsch, 2007). However, the widely expected magnitude of climate change in the next decades can exceed the adaptive capacities of many societies in all regions of the world, which implies a substantial conflict potential.

The implications for human societies can be expected to be greatest in regions with large population densities and a critical reliance on a functioning environment to maintain human welfare (IPCC, 2007a). One such region is the Mediterranean region, including southern Europe, the Middle East, and northern Africa. The Nile River basin in northeast Africa is directly connected to the Eastern Mediterranean and is an important lifeline, as more than one fifth of the African population lives within the river basin (World Bank, 2010). The population in the riparian countries continues to grow, augmenting the pressure imposed on the Nile River as the basic water resource. Studies on the implications of climate change on the Nile River indicate that the water resources in this part of the world are highly sensitive to possible changes in climatic conditions (Beyene et al., 2009; Conway et al., 2007). While it is not clear in which way the magnitude of precipitation will change in the long run (Elshamy et al., 2009), the irregularity and strength of extreme events is expected to increase. Furthermore, the temperature development is likely to lead to higher evaporation and water demand (Conway, 2005). Consequently, the future development of the overall water supply in the Nile River basin is highly uncertain in the light of changing environmental conditions.

The uncertainty in future water supply has profound impacts on economic activities, food security, energy supply and environmental quality in Northeastern Africa (Hulme et al., 2005; Yates and Strzepek, 1998) and thus on societal stability in general. Increased water scarcity requires societies to adapt to the altered conditions, for which it is necessary to develop appropriate management schemes (Iglesias et al., 2007). These management schemes can either lead to more cooperation as countries increasingly work together to allocate resources to the greatest possible benefit of all or can trigger disputes if actions by some countries lead to disadvantages of others.

This paper explores the possible implications of changes in water availability in the Nile River basin as a consequence of climate change. The next section focuses on how the Eastern Mediterranean and particularly the Nile River basin may be affected by climate change. Then the connections between the availability of water and conflicts in this region of Northern Africa are assessed in detail. The subsequent sections present an integrated assessment model that can be used to look at the possible development of domestic societal and international stability in the Nile River basin for different scenarios of climate change and show the results of preliminary assessments with the model. Section 6 discusses the results and draws some general conclusions.

2 Climate Change in the Mediterranean Region and the Nile River Basin

In the Mediterranean region (southern Europe, northern Africa, and the Middle East) global warming will likely increase the risks of societal instability, as a combination of factors contributes to the vulnerability of the population in that region (Brauch et al., 2003; Giannakopoulos et al., 2005; IPCC, 2007b; Stern et al., 2006):

- Rising temperatures are expected to exacerbate existing pressures on limited water resources because of altered rainfall patterns and losses of snow and glacial melt water. This adds to existing problems of desertification, water scarcity, and food production.
- Water scarcity has a negative impact on agricultural and forestry yields and limits the output of hydropower.
- Heat waves and forest fires compromise vegetation cover and add to existing environmental problems.
- Ecosystem change affects soil quality and moisture, the carbon cycle and local climate.
- Population pressure and water-intensive activities such as irrigation already impose a considerable stress on water supplies. This poses dangers to human health, ecosystems, and national economies of countries.

Within the Mediterranean region there are significant differences with regard to vulnerability and problem-solving capacity.

Southern Europe is characterized by relatively high economic and social capabilities, which can be further backed up by support from the EU to mitigate the impact and strengthen long-term adaptation possibilities (Brauch, 2006). Despite expected environmental changes, outbreaks of violence and conflict are less likely in the foreseeable future.

In contrast, the environmental situation in North Africa is significantly worse. Climate change interacts with the region’s other problems that involve high population growth, dependence on agriculture and weak governance. Countries are more vulnerable, less able to adapt and more prone to conflict.

In Southern Europe, a temperature rise of 2° C could decrease summer water availability by 20% to 30%; a rise of 4° C by 40% to 50% (Stern et al., 2006). Increasing temperatures, forest fires and water stress may lead to a general northward shift in summer tourism, agriculture, and ecosystems. Thus, climate change could endanger the tourism sector, the main employer in the southern part of the region. The Canary Islands, the south of Italy and Spain, and parts of Greece and Turkey already experience an increasing competition for resources with other economic sectors, especially for water and land. With increased warming, it may become increasingly difficult to sustain current living standards and provide development opportunities.

Lack of usable land and water resources adds to impoverishment and forces people to move from rural areas to cities. River deltas are at risk from sea-level rise and salinization. For 50cm sea-level rise salt water would penetrate 9 km into Nile aquifers, affecting agriculture and the whole economy (WBGU, 2008). Desertification may affect the stability of the Mediterranean region and possibly triggers large-scale migration, riots and violent clashes. This increases the pressure on European countries from African immigrants.

It is unlikely, however, that climate change alone leads to conflict, it will rather interact with other driving factors, such as unemployment, economic recession and unstable political regimes, to cause widespread dissatisfaction and, eventually, human insecurity and social instability. Whether and to which degree these developments will take place not only depends on climate stress factors and the human and socio-economic vulnerability, but also on the adaptive capacities of the societies affected that are used to contribute to deal with the implications of changing environmental conditions.

The focus of the assessments in this paper lies on the Nile River basin, a region that is of vital importance to the African continent. The Nile River is the longest river in the world. It is nearly 6700 km long and flows through ten countries before reaching the Eastern Mediterranean Sea (Figure 2.1). The main tributaries are the Blue Nile, which originates in the Ethiopian Highlands, and the White Nile that is fed by the waters from Lake Victoria. The sources of the White Nile lie in the mountains of Rwanda and Tanzania. The drainage basin comprises an area of more than 3.3 million km^2 (Beyene et al., 2009), which is approximately one tenth the size of the African continent.

Water supply into the tributaries of the Nile shows large fluctuations. In particular, the flow of the Blue Nile is subject to seasonal variability, as the majority of the runoff from the Ethiopian Highlands is collected during the summer monsoon between July and September (Beyene et al., 2009). The overall contribution of the Blue Nile to the total Nile water volume is approximately 60%. In contrast, the flow of the White Nile is steadier, mainly due to Lake Victoria, which serves as a large natural reservoir in the south. The precipitation regime of the White Nile is equatorial with two rainy seasons, a long one from March to May and one with shorter rainfall intervals from October to December (Conway, 2005). In the past century, the Blue Nile catchment basin has experienced a decline in rainfall from the mid-1960s until 1984. However, rainfall has increased again since then, returning to the long-term average rates. Rainfall in the Lake Victoria region has shown a particularly increasing trend starting in the 1960s. This has led to a rise in water level of the lake (Conway, 2002; Kite, 1981; Piper et al., 1986) until almost the end of the 20^{th} century. However, the water level of the lake has fallen continuously since then, which poses a significant problem for the production of hydroelectric power. Furthermore it has to be noted that the considerable evaporation in the swamps of southern Sudan decreases the water that is available further downstream to a significant extent, so that the relative importance of the White Nile as main tributary is reduced.

Both tributaries join in northern Sudan near the capital of Khartoum. The river continues through Egypt, providing a fertile lifeline in an environment that mostly consists of desert and shrublands (Fig. 2.2). However, only the downstream region of the Nile basin is dominated by deserts. The upstream countries mainly consist of grassland and shrubland. Notable biomes of the Nile River basin include the vast swamps in southern Sudan and the tropical and subtropical vegetation in the Ethiopian Highlands.

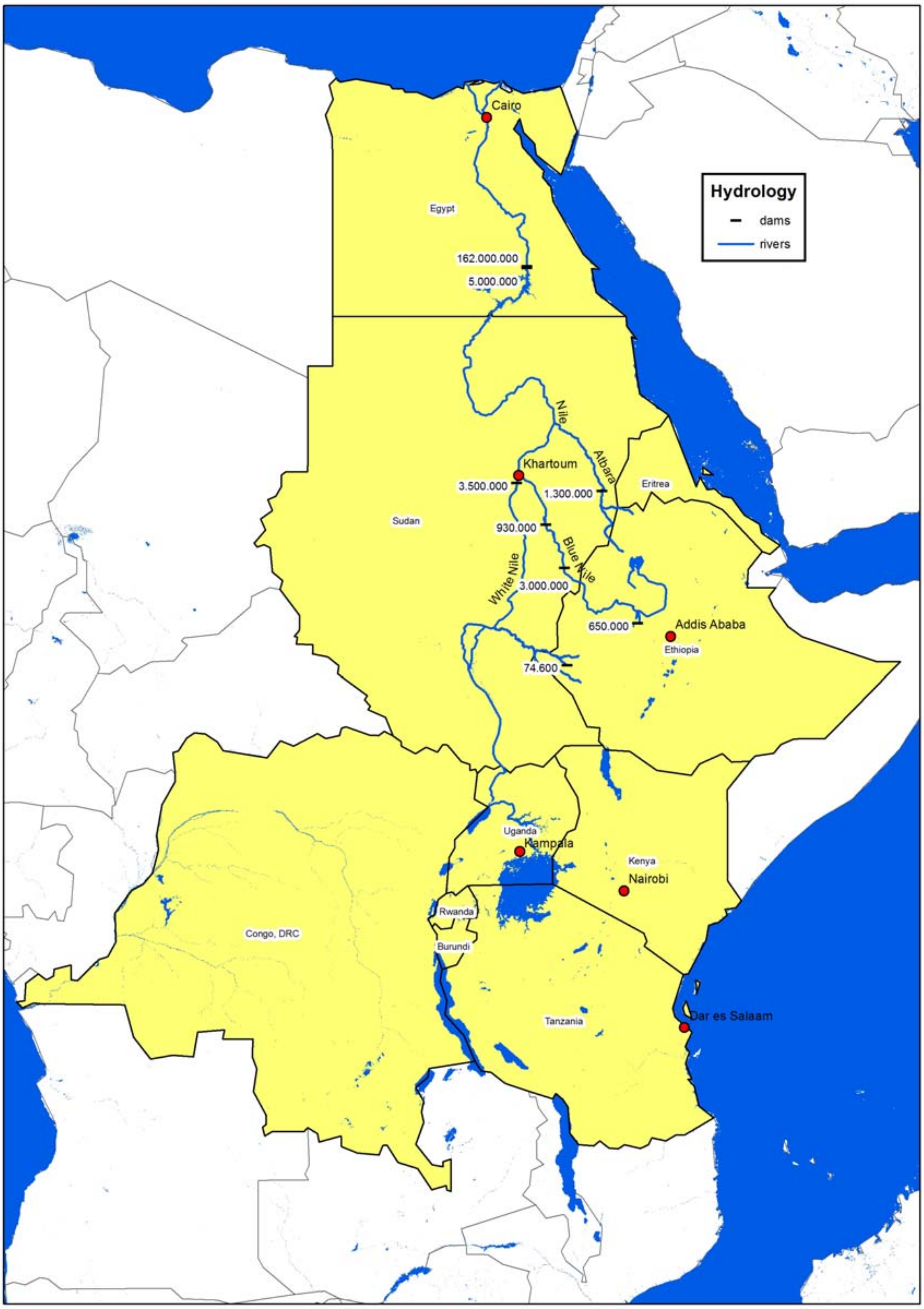


Figure 2.1: The hydrology of the Nile River system. The numbers in the figure refer to the storage capacity of the various dams in [1000 m^3].

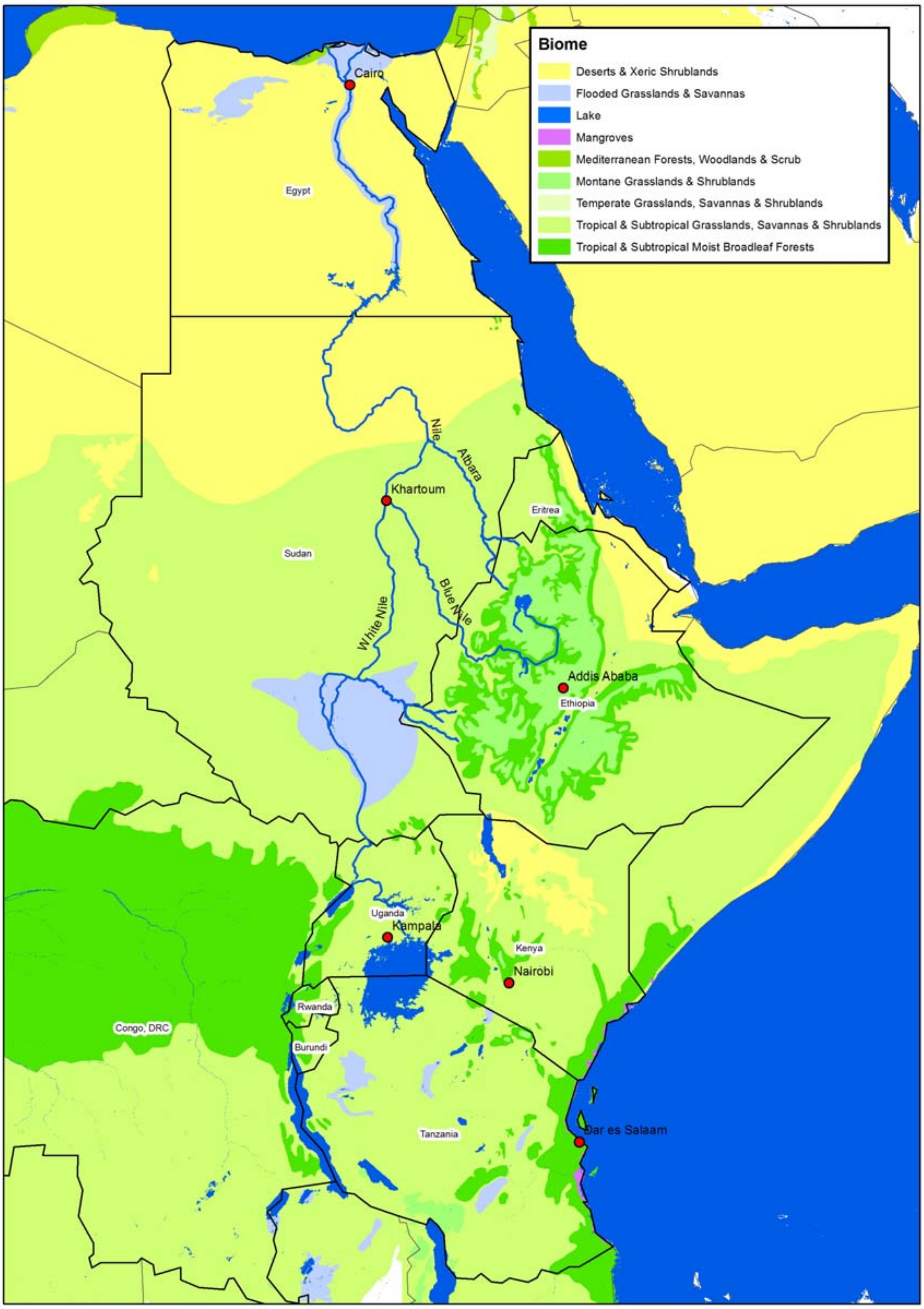


Figure 2.2: The biomes in the Nile River basin.

In the downstream region of the Nile River basin, the only arable land is in the direct vicinity of the river. In the past, extensive floods have covered the floodplains with nutrients and fresh sediments. This has changed to a large extent since a series of dams has been erected to control the flow of the Nile River. The Aswan High Dam, which was completed in 1970 (Tesfaye, 2008), is the most prominent dam of the Nile River system. It is located in southern Egypt near the Sudanese border and was constructed to manage the flow of the Nile through Egypt in order to improve agricultural productivity, generate electricity for industrial purposes and to artificially manage the seasonal floods in the Lower Nile region. There are three other major dams altering the flow of the Nile and numerous smaller ones influencing the water availability in the ten riparian countries. While the water supply is obviously greatest in the upstream countries, especially in Ethiopia, the demand for water from the Nile is largest in the downstream countries Egypt and Sudan. This necessitates the establishment of formal agreements to manage the water resources, as uncertainties over future water allocation from the Nile could very well lead to armed conflicts in the wake of high uncertainties about the future development of Nile flows (Swain, 1997).

In the past, water flow of the Nile has shown considerable variability (Fig. 2.3). The downstream flows have become markedly lower and less variable after the completion of the Aswan High Dam. In the last century, flows of the Blue Nile have ranged from 20 km^3/a to almost 80 km^3/a (Conway, 2005) with an average flow of about 46 km^3/a. The decline in precipitation in recent decades also becomes evident in flow rates as the lowest decadal average in Blue Nile flow stems from the period 1978-1987. In contrast, flow in the White Nile has increased due to the doubling of outflow from Lake Victoria in 1961-1990 compared to 1931-1960, but has declined again in the recent past. Annual flows in the downstream part of the Nile River resemble a composite image of the two principal tributary systems as the other sources contributing to the Nile River are only of secondary importance.

Due to its considerable socio-economic importance for a significant share of the African population (more than one quarter lives in the Nile River basin), the water resources of the Nile River have been the focus of many studies assessing the possible consequences of climate change on this region. Initial assessments with simulation models show that changes in temperature and precipitation in the Nile Basin as a consequence of climate change could be severe (Hulme, 1994; Strzepek et al., 1996), as global warming and a concurrent decrease in precipitation could lead to a lasting decrease in river flow of the Nile. However, simulations for scenarios with higher CO_2 concentrations have proven inconclusive: for a doubling of CO_2 in the atmosphere, future river flows could range from a 30% increase to a 77% decrease (Strzepek et al. 1996).

The large range of possible consequences of changes in climatic conditions for the flow rates of the Nile River can be attributed to the complexity of the river system. Flows of the White Nile are extremely sensitive to the water level of Lake Victoria and its amount of water released (Sene, 2000). These are affected by changes in precipitation rates to a much larger degree than by changes in land use in the catchment area. There are also substantial effects on the flows from the Blue Nile: Using climate change scenarios based on results from general circulation model (GCM) simulations, the simulations conducted by Kim and others (2008) suggest that the climate in most of the Upper Blue Nile River Basin is likely to become wetter and warmer by the 2050s. Low flows may become higher and severe long-term droughts are likely to become less frequent throughout the entire basin.

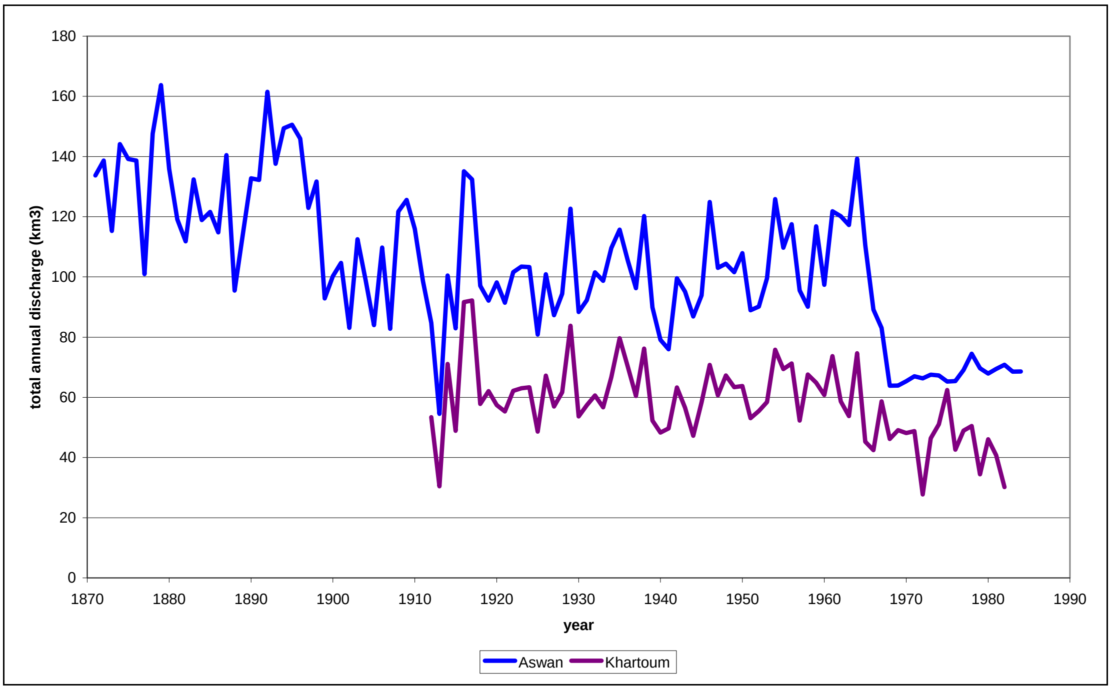


Figure 2.3: Water flow in the Nile River system, based on (Vörösmarty et al., 1996, 1998).

Such changes in the variability of runoff from the Ethiopian part of the basin are likely to have a profound impact on the downstream countries of the Nile River Basin. The consequences of climate change are not necessarily negative, since the large dams with their associated storage capacities can alleviate large fluctuations in Nile flows. If the assumed changes in climatic conditions do not drastically reduce flow rates in the upstream countries, the region is likely to have the future potential to produce hydropower, increase flow duration, and water storage capacity without affecting outflows to the riparian countries by the middle of the 21^{st} century (Kim et al., 2008). However, if the more pessimistic scenarios actually turn out to be true, a shift in water management goals is necessary to rather invest capital to decrease water demand via more efficient irrigation management instead of investing in projects that may become ineffective as a result of climate change (Strzepek et al., 1996). Particularly, if water availability from the Nile River is declining in the long run, such a development can create tensions between the various riparian countries that are based on the profound discrepancies in economic power, individual welfare and societal stability between the upstream and downstream countries that have evolved in the past and that could become even more serious in the future.

Egypt and especially Cairo are particularly vulnerable to various impacts of climate change. Egypt could experience a severe loss in agricultural productivity as a result of climate change induced water scarcity and land degradation (Agrawala et al., 2004). Wheat and maize production in Egypt could significantly drop by middle of the 21^{st} century. Even without the continuing mounting demographic pressure, this may intensify competition over remaining arable land.

The capital's infrastructure is already under pressure due to the Cairo's rapid growth, especially with respect to water availability, hygiene, waste disposal, and housing. Climate change is likely to even worsen existing problems. A 0.5m rise of the sea level of the Mediterranean Sea may displace between two and four million Egyptians (FoEME, 2007). Most of them will seek refuge in Cairo's suburbs. Water scarcity and lower agricultural productivity in the Upper Nile area may also add to migration from the rural areas to Cairo and contribute to degradation of sanitary conditions and increasing social unrest as well.

3 Water, development and conflict potential in the Nile River basin

3.1 A region marked by inequalities

The Nile River basin has an extremely long cultural heritage. For many millennia humans have dwelled in the vicinity of the Nile River. A complex socio-economic system has evolved over time. Today, ten sovereign countries exist in the Nile River basin.

The relations between the countries of the Nile Basin are characterized by the large inequalities between them, in the political as well as the environmental, economic and developmental realm (Allan, 2009). This is illustrated in Figure 3.1, using selected indicators for each dimension as described in the following. Egypt clearly possesses the dominating economic and political power in the region. GDP and foreign direct investment are both about a factor three larger than that of the closest contestant Sudan[1]. The political power is quantified using the Composite Index of National Capabilities (Singer, 2005), which combines data on energy consumption, iron and steel production, military expenditure, military personnel, total and urban population (Singer, 1987), as well as the government effectiveness indicator from the World Bank (Kaufmann et al., 2008; Governance Matters, 2009). Partially due to its political and economic domination, Egypt is also the most successful country in regards to development. It has the highest Human Development Index[2], almost no malnourishment (which is actually largely due to food imports), almost complete electrification and, what is most important for the relations with respect to water in the basin, the highest degree of exploitation of its potentials in the areas of irrigation and installed hydroelectric power (HEP). While the other countries have larger potentials in both areas (specifically Sudan for irrigation and Ethiopia for HEP (Amer et al., 2005)) as well as the demand (due to chronic food shortages in both countries as well as increasing energy demands), until now they have not been able to exploit this potential. This contrasts strongly with the principal upstream dominance in the environmental dimension – the area of potential arable land (both for rainfed and irrigated agriculture) and especially the internally produced renewable water. Egypt

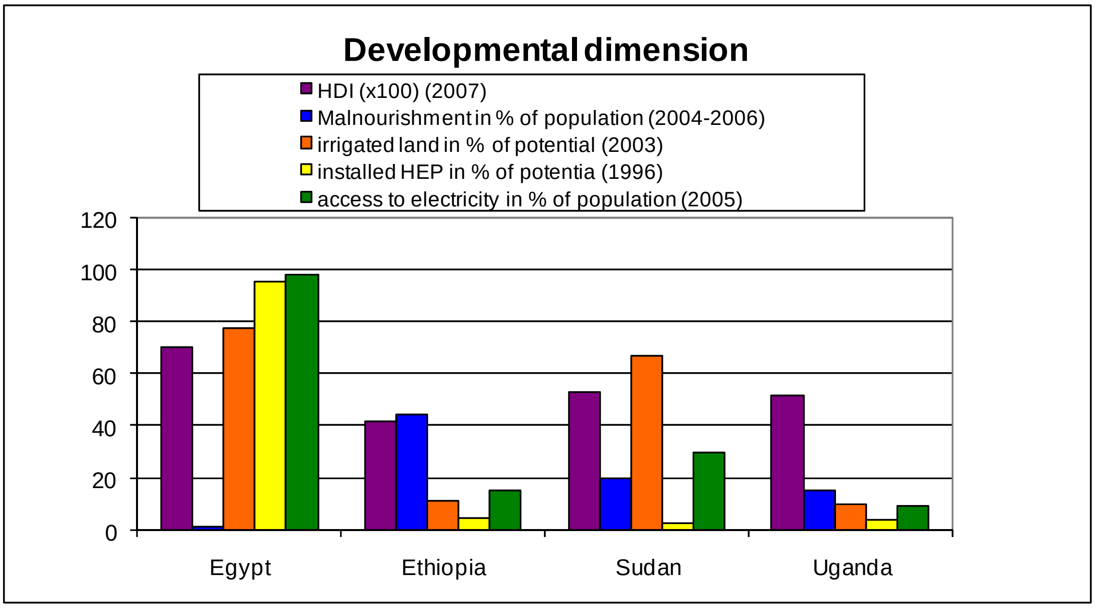
[1] The economic success of Sudan is a rather recent phenomenon due to the exploitation of oil after the conclusion of the Comprehensive Peace Agreement with South Sudan.

[2] With rank 123 it is classified as medium developed country. Sudan (rank 150) and Uganda (rank 157) barely fall in this category (ranks 84 to 158) and Ethiopia (rank 171) is one of the overall lowest developed countries UNEP: 2009, Human Development Report 2009 - Overcoming barriers: Human mobility and development, New York..

has a dependence on external water of 97%, 86% of which comes from Ethiopia and the rest from the White Nile (FAO, 2010a). Also the upstream states have an advantage in agricultural opportunities due to large amounts of soil water (Allan, 2009).

These inequalities translate into very different capabilities to react to one of the major challenges for the Basin countries: unhindered population growth. The associated demand increase for food and development in turn lead to a significantly increased need for water, which hence intensifies water scarcity. Falkenmark (1989) classifies countries according to their availability of renewable water per capita in *relative sufficient* (>1700 m^3/capita/a), *stressed* (>1000 m^3/capita/a), *scarce* (>500 m^3/capita/a) and *severely scarce* (< 500 m^3/capita/a). According to this classification Egypt is already a water scarce country (Fig. 3.2) and the others will also reach this category by about 2030, assuming increasing populations (FAO, 2010b) and constant available amounts of renewable water.

The adaptive capabilities can be illustrated, following Ohlsson (2000), by comparing hydrological water scarcity and social water scarcity which takes into account the degree of development and therefore also the adaptive capability[3]. Figure 3.3 illustrates the high adaptive capabilities Egypt possesses to tackle its existing large water scarcity. An example for this is the import of 'virtual water' – food which would consume large quantities of water if produced internally (Allan, 2009).



[3] HWSI = hydrological water scarcity index = scarcity caused by the amount of naturally available water, measured in millions of people per m^3 of water
SWSI = social water scarcity index = HWSI/Human Development Index, scaled with a factor of 0.5

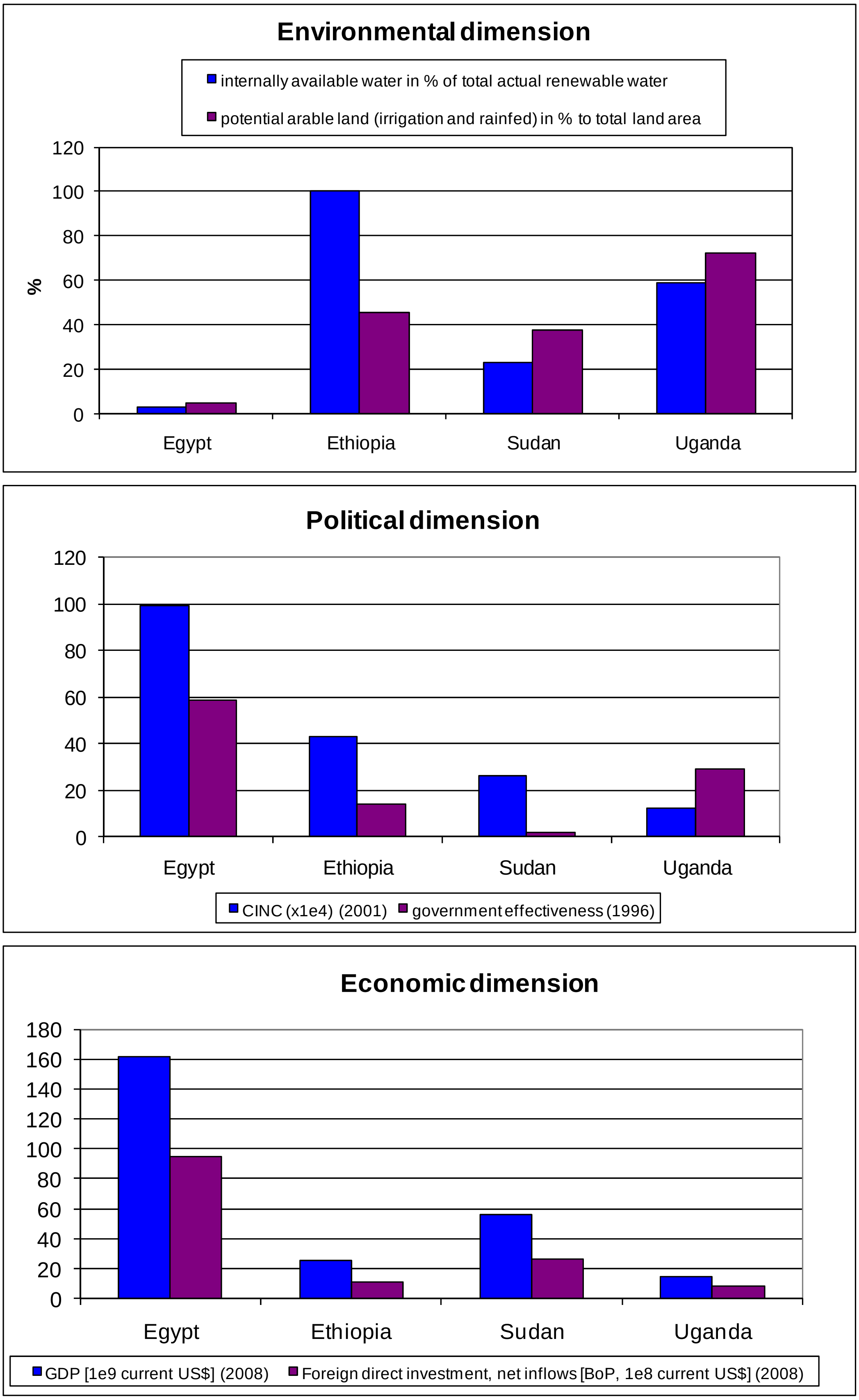


Figure 3.1a-d: The four dimensions of inequality in the Nile Basin. The term CINC denotes the Composite Index of National Capability (Amer et al., 2005; CIA, 2010; FAO, 2010a, c; Kaufmann et al., 2008; Pacific Institute, 1999; Singer, 2005; UNEP, 2009; World Bank, 2010; World Resource Institute, 2010)

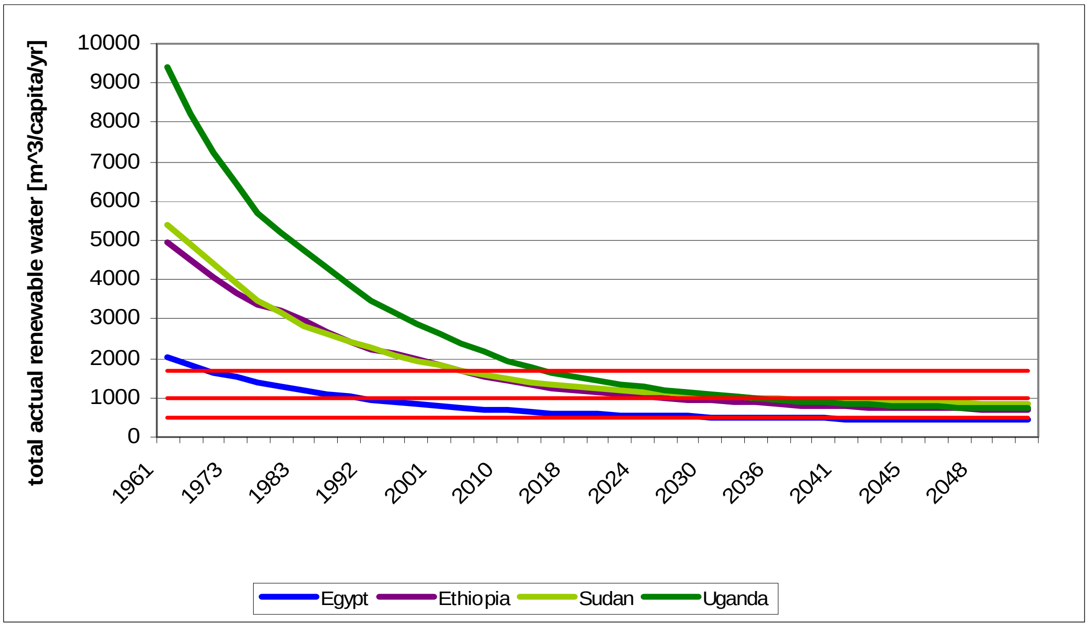


Figure 3.2: The actual renewable water resources for the four main Nile Basin states projected into the future. Data sources: (FAO, 2010a, b)

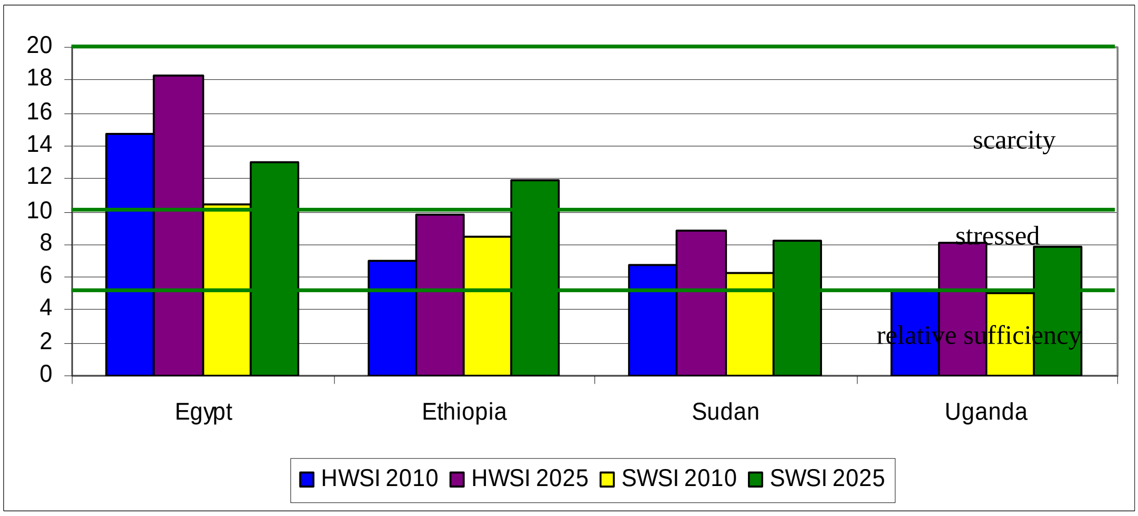


Figure 3.3: Comparing hydrological water scarcity (HWSI) with social water scarcity (SWSI). The green lines indicate the classification according to the Falkenmark water stress index as described in the text. While water scarcity measured with this indicator increases in the future due to population growth, the adaptive capabilities are illustrated in the SWSI and put water scarcity into a wider perspective. The predictions for 2025 are based on population predictions with fixed available water and HDI. Data sources: (FAO, 2010a; UNEP, 2009; UNPD, 2008)

As shown in Figure 3.3, Egypt is supplementing its available renewable water with substantial amounts of virtual water, which is almost completely imported from the world market rather than from inside the basin. In contrast and despite its high degree of malnourishment and recurring famines, Ethiopia's trade in virtual water is negligible (Figure 3.2). The country is in urgent need to find ways to address its looming water scarcity[4].

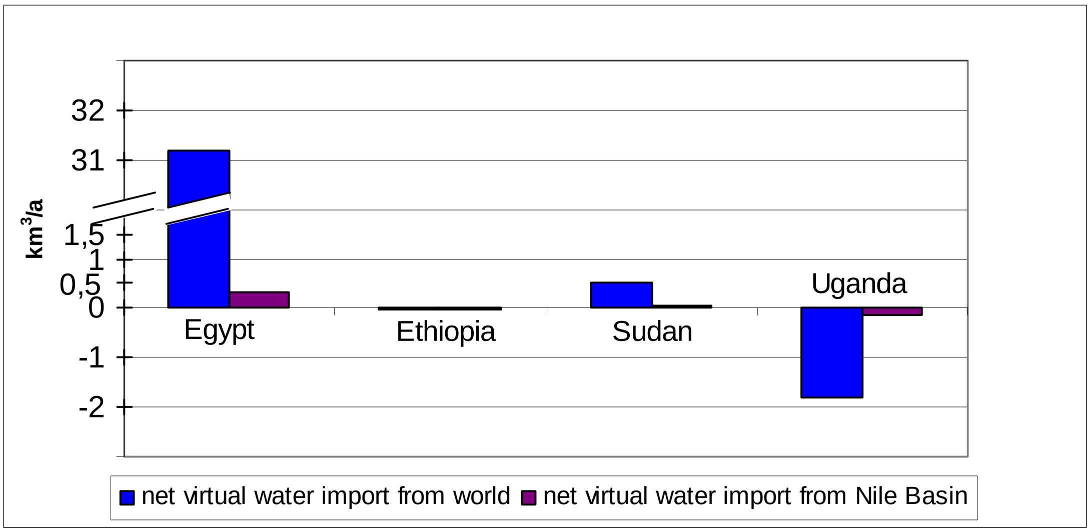


Figure 3.4: Virtual water import as a way to adapt to water scarcity. Data source: (Allan, 2009).

3.2 Water agreements

In order to compensate its environmental disadvantage, Egypt has used its economic and political power to maximize its water access. Despite its position as a downstream country not contributing at all to Nile waters, it currently uses most of the water according to prevailing agreements – together with Sudan a total of 87% (Waterbury, 1979). This is based on two historic agreements. The first is the Nile Waters Agreement of 1929 between Egypt and the colonial power Great Britain[5] which recognizes Egypt's historical rights to the Nile. Secondly there is the 1959 agreement between Egypt and Sudan on the "full utilization of the Nile Waters", which establishes 'acquired rights' for both states, disregarding the other riparians[6,7]. Both agreements are not recognized by the upstream riparians since they were not involved (Arsano and Tamrat, 2005) and their rights to develop their own water resources were neglected. Ethiopia stated already in 1956 that it "has the right and obligation to exploit its water resources for the benefit of present and future generations of its citizens (and) must, therefore, reassert and reserve now and for the future, the right to take all such measures in respect of its water resources" (Addis Tribune, 1999, found in Tafesse, 2001). This ignorance of the upstream needs has been reason for

[4] Water scarcity in Ethiopia is not due to lack of water, but to a high degree of spatial and temporal variability in rainfall Arsano, Y. and Tamrat, I.: 2005, 'Ethiopia and the Eastern Nile Basin', Aquatic Sciences - Research Across Boundaries 67, 15-27..

[5] Great Britain signed on behalf of all territories in the Nile Basin under British administration – Sudan, Uganda, Kenya, Tanzania.

[6] This agreement is based on the mean annual flow at Aswan between 1900 and 1959 measured as 84 billion m^3 per year. The shares are proportionate, with Egypt being awarded 66% or 55.5 BCM/yr and Sudan 22% or 18.5 BCM/yr. The losses due to evaporation from Lake Nasser are estimated at 10 BCM/yr. Waterbury, J.: 1979, Hydropolitics of the Nile Valley, Syracuse University Press, Syracuse, N.Y., p. 301.

[7] For a full list of agreements between Nile Basin countries see Hefny, M. and Amer, S.E.-D.: 2005, 'Egypt and the Nile Basin', Aquatic Sciences - Research Across Boundaries 67, 42-50.

simmering tensions for the past 60 years[8], mainly between Egypt as the main consumer and Ethiopia as the main origin of the downstream Nile waters[9]. However, the continuing political instability, civil wars and involvement in external conflicts in the upstream states has prevented large-scale investment in the development of water resources in these countries and allowed Egypt to fully utilize its share as agreed upon in the 1959 agreement[10].

This difference in utilization and investment is reflected in the degree of realization of the respective potential for irrigation and hydro-electric power (HEP) in the countries (Fig 3.1, developmental dimension). While Egypt manages to utilize most of its potential, all upstream states lag far behind. Any attempts of the upstream states to develop its water resources and utilize their potentials were blocked by Egypt through a policy which prevented large international funding agencies like IMF and World Bank to fund projects related to transboundary water resources without approval from the downstream riparian states (Waterbury, 2002; World Bank, 1994). Egypt's position is based on the claim that there is no potential to reduce its share of the Nile waters because it is fully utilized and needed. Therefore any upstream development is potentially endangering Egypt's supply. Studies have shown, that this is not necessarily true and the impact might be rather small (Block et al., 2007; Guariso and Whittington, 1987). At the same time Egypt's large land reclamation projects like the New Valley Project (Lonergan and Wolf, 2001) can be interpreted as an attempt to put facts on the ground which ensure this full utilization of water, while insufficient emphasis is being put on attempts to increase the efficiency of water use or to reallocate water to other sectors rather than agriculture (Mason, 2004). Such measures could however also be a source for internal strife since water in Egypt is highly subsidized especially for agriculture (Abou-Ali, 2003), a sector which still employs about 40% of the workforce (World Resource Institute, 2010).

Because of its leading and influential role in all respects of the Nile Basin, Egypt has been characterized as a hydro-hegemony with the central material, bargaining and ideational power (Zeitoun and Warner, 2006). Despite recurring hostile rhetoric, for decades no upstream country was able to challenge Egypt's hegemony.

3.3 The current situation

Over the past 20 years cooperation among the Nile Basin states has been increasing. The reasons for this lie in the relative strengthening of the upstream states, which enables them to increasingly challenge Egypt's ideational and bargaining power, as well as their absolute need to act because of rising population pressure. The

[8] An example is an often cited quote by Boutrous-Ghali (1988): "The next war in our region will be over the waters of the Nile, not politics", but also numerous statements by Ethiopia emphasizing its water rights and announcing planned developments like dams and irrigation systems Pacific Institute: 2009, 'Water Conflict Chronology'..

[9] This state of tensions seems typical for areas with a water conflict – despite the conflictive nature, so far there has not been an interstate war over water Wolf, A.T.: 1998, 'Conflict and cooperation along international waterways', Water Policy 1, 251-265..

[10] In fact, it even over-utilized it since Sudan was unable to fully exploit its share due to continuing economic crisis. This is changing now due to new investments and interest in the development of the water sector Hamad, O.E.-T. and El-Battahani, A.: 2005, 'Sudan and the Nile Basin', Aquatic Sciences - Research Across Boundaries 67, 28-41.

strengthening can be observed in three areas: the political, economical and external one.

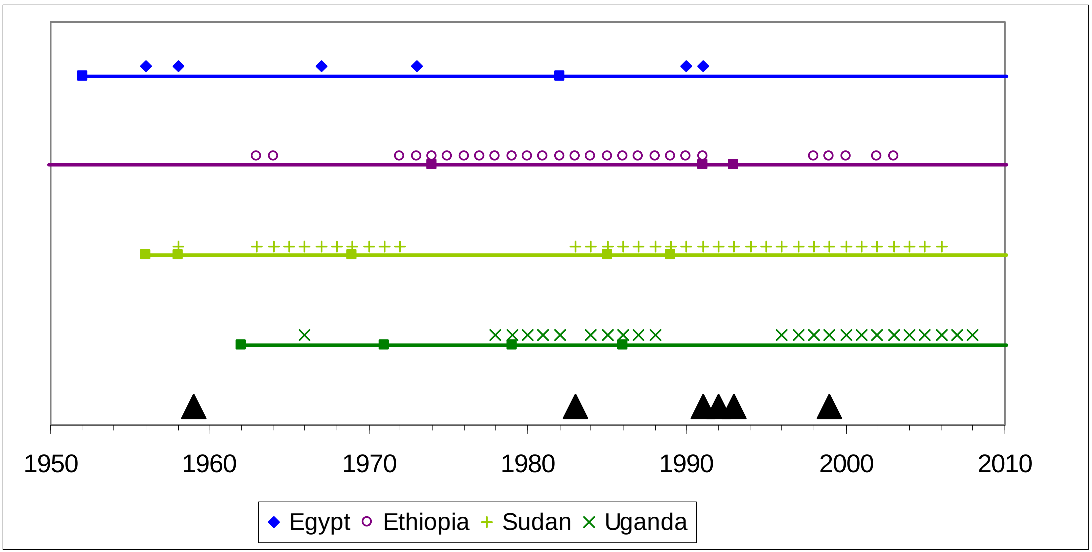


Figure 3.5: Analysis of the political stability as possible reason for increased cooperation after 1990. The discrete small symbols indicate years a state was involved in one or more conflicts (intra and inter-state conflicts, data source: (Singer, 2005). The squares connected by solid lines indicate the political situation – squares stand for military coups[11] and the lines for times with peaceful changes in power via elections (this does not contain information about the level of democracy or legitimacy of the government). The large black triangles indicate years of major cooperative agreements: 1959 between Egypt and Sudan, 1983 the Undugu initiative (until 1993), 1991 between Egypt and Uganda, 1992 the start of the Nile 2002 conferences and TECCONILE, 1993 the agreement between Egypt and Ethiopia[12] and 1999 the start of the NBI and the revival of the East African Community.

Politically this means a reduction of internal and international conflicts the states are involved in as well as an internal stabilization of the government (not necessarily meaning democratization). An attempt to illustrate this has been made in Figure 3.5, showing the involvement of basin states in conflicts[13] as well as the years with changes in government caused by coups (squares connected by line). The long-term stability in Egypt is clearly visible, including a stable (though authoritarian, especially since the declaration of the State of Emergency 1982) government. The other states have been involved in conflicts also more recently or still are currently (the details of which are beyond the scope of this article), but have a stable government since 1986 (Uganda), 1989 (Sudan) and 1991 (Ethiopia) in common.

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[11] Except 1983 in Egypt – this indicates the declaration of the state of emergency which still is in effect today.

[12] Neither country should undertake projects with respect to Nile waters which harm the other, both should consult and cooperate and comply with international law – for full text see http://ocid.nacse.org/tfdd/tfdddocs/521ENG.pdf

[13] The involvement in conflict is denoted by the symbols indicated in the legend, without specification of the type or number of conflicts at a given time. The information is based on the Correlates of War Database War list Sarkees, M.R. and Wayman, F.: 2010, Resort to War: 1816 - 2007, CQ Press, Washington D.C., p. 577, Singer, J.D.: 2005, 'Correlates of War Database - Dataset on National Material Capabilities - Version 3.02 '..

The increasing stability facilitates economic growth and frees funds through decreasing military spending. While Egypt is still by far the dominant economic power in the basin, the other states enjoy constant impressive growth rates (Fig. 3.6). Specifically Sudan benefits from the exploitation of its oil resources after the Comprehensive Peace Agreement, while Ethiopia was the fastest-growing non-oil exporting country in Sub-Saharan Africa 2007/2008 (IMF, 2008). Such growth rates increase the demand for energy and water, but at the same time enable states to fund projects with own resources. An example is the recently inaugurated Tana Beles Dam in Ethiopia (Ethiopian News, 2010). On the other hand, the growth is also facilitated by increased external support from new actors, such as China as a new large investor in Africa and the Gulf States who try to secure land for agriculture to increase their own food security. These new players help the upstream states to avoid the Egyptian veto on water-related projects (Cascão, 2009).

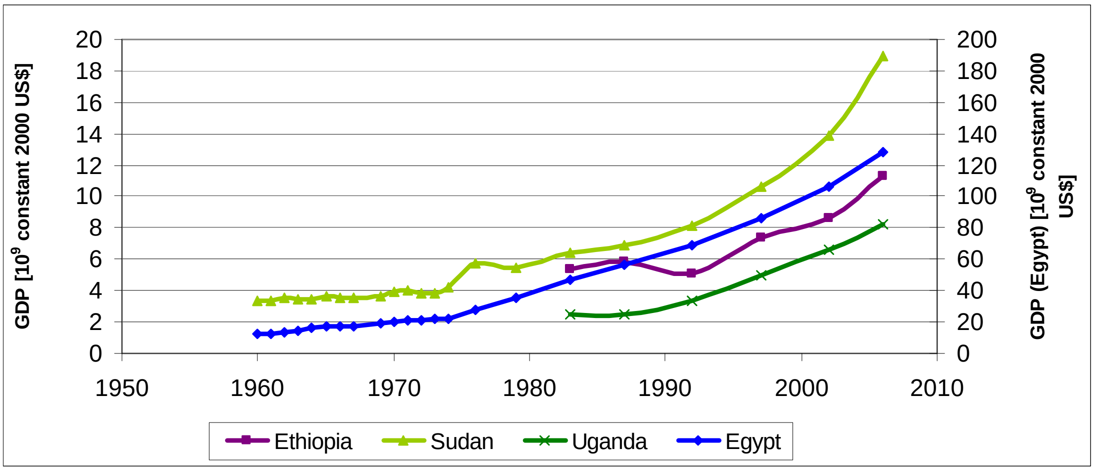

Figure 3.6: GDP development – due to Egypt's predominance its data are plotted on the right axis, data source: World (World Bank, 2010)

The rising self-confidence of the upstream states combined with their increasing ability to realize own water resource projects to utilize their irrigation and HEP potential, challenges the status quo and threatens Egypt's high water use. This is particularly important for projects in Ethiopia, the main water source for Egypt, but also for the equatorial states, who increased their political weight by reviving the East African Community (Kagwanja, 2007). Instead of leading to tensions, this development has fostered cooperation among the Nile countries. Major agreements and cooperative initiatives are marked with large black triangles (Fig. 3.5). While bilateral agreements are included, the multilateral initiatives are more important. They started after 1990[14] with the launch of TECCONILE[15] (1992-1998) and the related Nile River Basic Action Plan, and continued with the series of 'Nile 2002' conferences 1993-2002 and the launch of the Nile Basin Initiative 1999[16].

[14] The earlier Undugu initiative (1983-1993) did not include all Nile Basin countries, especially not Ethiopia, and did not directly address the water issue Shapland, G.: 1997, Rivers of Discord, C. Hurst & Co., London..

[15] Technical Cooperation Committee for Promotion of the Development and Environmental Protection of the Nile Basin

[16] For details see the NBI website http://www.nilebasin.org/ and Nicol, A., van Steenbergen, F., Sunman, H., Turton, T., Slaymaker, T., Allan, T., de Graaf, M. and van Harten, M.: 2001,

Cooperation follows a two-track approach. One track pursues specific projects and technical cooperation, whereas the other entails negotiations with the goal of a comprehensive basin-wide agreement. These so-called D3 negotiations have been in progress since 1997 and a draft Cooperative Framework Agreement (CFA) has been on the table since 2007 (NBI, 2007), but for three years the states failed to sign and ratify the document due to irreconcilable differences between Egypt and Sudan on the one side and the seven upstream states on the other side. The disagreement mainly concerns the question of the relation between the CFA and the previous agreements from 1929 and 1959, since especially Egypt is unwilling to negotiate its share of water under the 1959 treaty, regarding this as a matter of national security (Hefny and Amer, 2005). The positions of both sides are summarized in Table 3.1, led by the two main principles of international water law – no riparian state should cause harm to another, and the right of all riparians to use the shared water resource equitably (Salman, 2007).

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

Table 3.1: Positions of states regarding the Cooperative Framework Agreement. In this context, downstream states are Egypt and Sudan, upstream states are Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, and Democratic Republic of Congo. (Source: own compilation).

The split between the basin states was deepened when, after several rounds of unsuccessful negotiations, the upstream states decided to open the CFA for signature on May 14 2010 without the approval of Sudan and Egypt, under the premises that under this agreement no party has any veto rights and developments regarding Nile waters have to be undertaken cooperatively following the principle of equitable use (NBI, 2010). The first signatories were Ethiopia, Uganda, Rwanda and Tanzania, Kenya followed on May 19 (Al Masry Al Youm, 2010). Kenya’s Minister for Water Charity Ngilu declared “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 denounced the move and immediately started intense diplomatic efforts to restart negotiations. Additionally, Egypt increased the pressure on the upstream states, for instance by pushing international funding agencies to cancel funding[17] (AFP, 2010; Bikya Masr, 2010). Egypt might also take the case to international arbitration unless this is refused by upstream states (Al-Ahram Weekly, 2010). At this

'Transboundary water management as an international public good', Ministry of Foreign Affairs, Stockholm, Sweden.

[17] Funding from sources like the IMF and World Bank was previously strongly increased within the NBI framework.

point it is too early to assess if this is the end of basin-wide cooperation and the start of a new era of hostility and unilateral moves. If so, climate change is likely to increase tensions further due to the lack of basin-wide mechanisms to deal with fluctuating and changing water resources. This could include the possibility of violent conflict over water in the region.

On the other hand, a basin-wide agreement, once achieved, could create a win-win situation for all parties if the comparative advantages and power assets of each country are taken into account. Scenarios for this have been discussed widely (see for example Mason, 2004; Whittington, 2004; Wichelns et al., 2003). Important to mention here is again the large potential for HEP in Ethiopia, which could enable exports of electricity to the neighboring states, and the advantages of damming water upstream rather than downstream due to less evaporation losses[18]. The overall unused irrigation potential in the basin is larger than the water available for irrigation (FAO, 1997), pointing to the need to identify the most optimal water use (Ribbe and Ahmed, 2006). The flat and fertile lands of Sudan, often referred to as the "bread basket for the Arab world" (Donovan, 1996), offer a large agricultural potential. Allan (2009) also points to the importance of soil water as an advantage of the upstream states. Generally, an increased trade in food crops and livestock (i.e. in virtual water) within the basin (rather than with the outside world as shown in Figure 3.4) would more effectively distribute the water consumption of agriculture and foster ties between the basin states. Egypt could focus on less water intensive cash crops and finance projects in the upstream countries in return for food and electricity. There is an especially high incentive for cooperation between Sudan and Ethiopia in the area of watershed management, since Ethiopia would benefit from dams for HEP and irrigation and Sudan would benefit from the flood control, decreased siltation and import of electricity and irrigation water. This puts Sudan in a unique position between the upstream states and Egypt. While it could weaken the traditional alliance between Sudan and Egypt (Tafesse, 2001; Wu and Whittington, 2006), it makes Sudan the "Master of the Middle" (Waterbury, 2002), a potentially crucial actor to overcome the differences in the basin (Cascão, 2009). At the same time the unpredictable and instable political development in Sudan with next year's referendum on the independence of South Sudan leaves Sudan as a vulnerable partner. Recent elections have resulted in Omar al-Bashir retaining power, which makes a referendum less likely. An again destabilized Sudan could then change the situation in the Nile Basin considerably and potentially increase the number of Nile riparian states by one in 2011. This insecurity is further increased by the unclear impact of recent elections in Sudan and Ethiopia, which reaffirmed both President Al-Bashir and Prime Minister Meles Zenawi in power despite claims of fraud and irregularity.

Finally, it should be emphasized that projects which could help alleviate water scarcity can also generate new internal conflict potential especially through the impacts on people's traditional way of living and the need for large-scale resettlement. New dams in Ethiopia and Uganda have already generated such controversy[19]

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[18] This point has already been recognized in the 'Century Storage Scheme' Hurst, H.E., Black, R.P. and Simaika, Y.M.: 1946, 'The Nile Basin, Vol. VII: The Future Conservation of the Nile', Government Printing Office, Cairo..

[19] Also from an environmental perspective – see the report by the World Commission on Dams (2000), http://www.unep.org/dams/WCD/report.asp. Also the health consequences of dams and irrigation canals have to be considered.

(Hathaway, 2009), and the Jonglei project in southern Sudan also led to violent disruptions during the initial construction phase and whenever resumption of construction, which has been suspended, is discussed[20] (Collins, 1996). These impacts should be taken into account when planning water projects.

A stringent management of the water resources of the Nile is essential for a peaceful coexistence of the Nile River states and the stability of the entire region. Changes in water supply over an extended period, e.g. a long-term reduction due to decreased rainfall in the upstream countries, bear a conflict potential for the countries in the whole basin (Mason, 2004). Egypt depends on the Nile for 95% of its drinking and industrial water and could feel threatened by upstream countries that deplete the water resources from the river. While this increases the chances for political crisis and violent clashes (Brauch, 2006), it also increases the necessity for agreements to regulate water distribution. Lack of usable land and water resources adds to impoverishment and forces people to move from rural areas to cities. However, the agriculturally quite productive river delta is at risk from sea-level rise and salinization (WBGU, 2007).

4 Model framework for the assessment of conflict potentials and cooperation

In order to be able to assess the possible consequences of changing environmental conditions on societal stability in the Nile River basin, it is necessary to understand how climate change could influence resource availability, economic wealth, and the probability of conflicts arising. The interactions and causal relationships between the various driving factors influencing societal stability in the Nile River basin are shown in Figure 4.1. In this diagram, a green arrow indicates a positive impact, i.e. an increase of one factor causes an increase in the factor that is affected. A red arrow represents a negative impact, which implies that an increase in a particular variable leads to a decline in the variable that is affected. A black arrow represents a feedback that is ambivalent. No arrow implies that no relevant impact is considered.

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

[20] Construction of this canal to decrease evaporation losses in the Sudd Swamp in South Sudan was halted after attacks in the Sudanese civil war 1983 Collins, R.O.: 1996, The Waters of the Nile: Hydropolitics and the Jonglei Canal, 1900-1988, Oxford University Press..

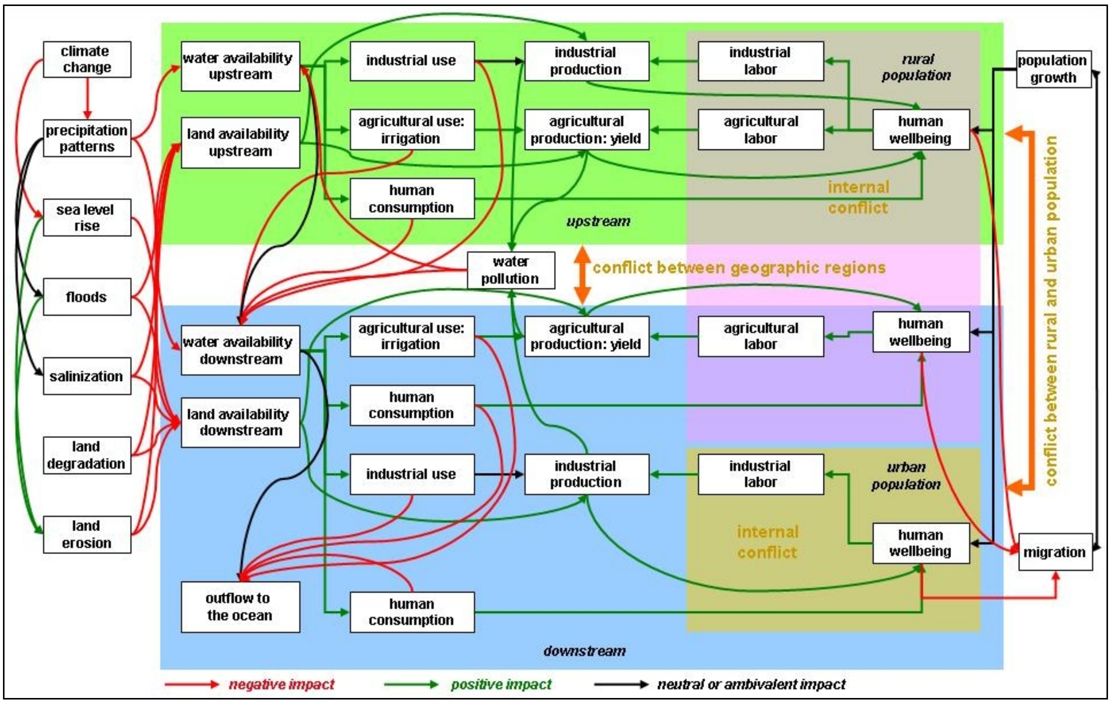

Figure 4.1: Schematic overview of the water conflict in the Nile River basin.

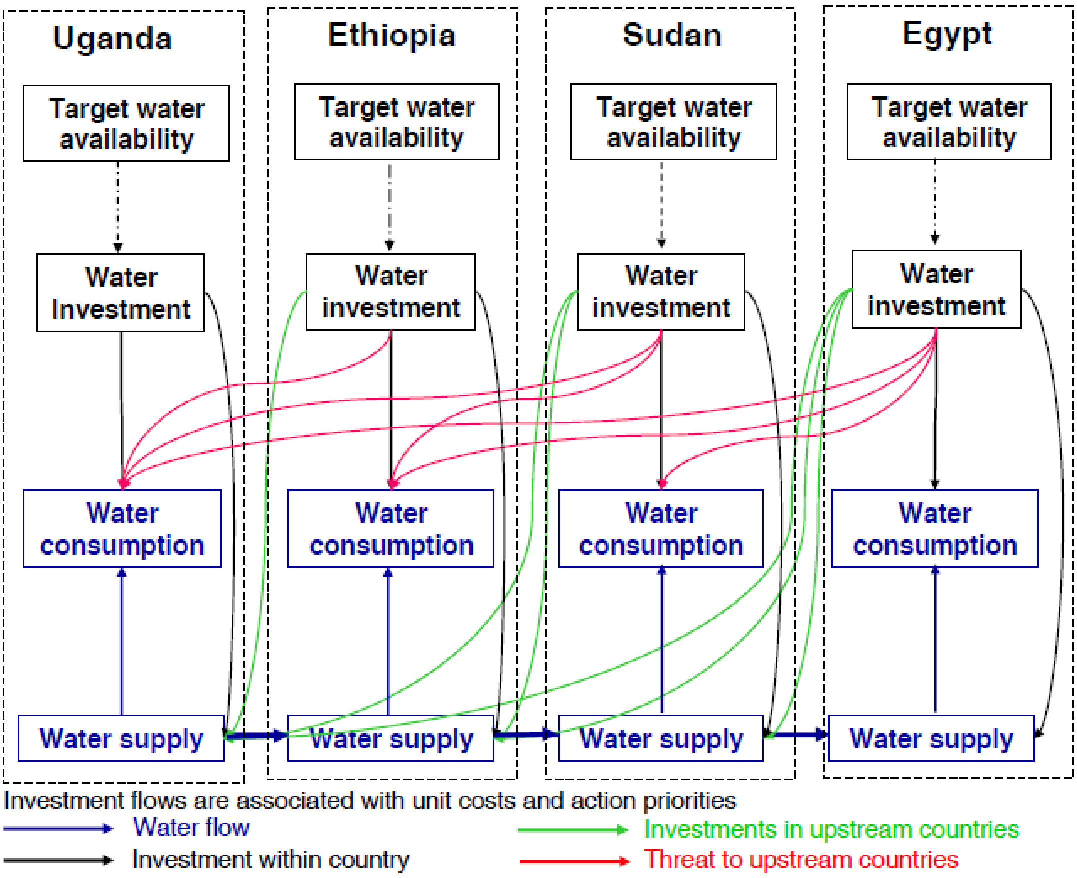

Figure 4.2: Interactions between the countries in the simulation model.

Conflicts between the various actors can arise on different levels. First of all, there can be tensions between geographic regions. Increased use of resources in the upstream region diminishes the conditions for successful agricultural production downstream. Also, tensions may build due to the distinctly different structure of the populations in the rural and urban regions. These may increase in intensity if migration between these regions or particularly large population growth leads to larger competition over the limited resources available. Such conflicts are by no means limited to tensions between regions but could also manifest themselves in internal conflicts within a particular part of society.

Against the background of the impact graph of Figure 4.1, we will focus on the interactions regarding water use and availability in the Nile River Basin. For the four major riparian countries (Egypt, Sudan, Ethiopia, Uganda), we will discuss the options of each country for investing into water use and supply, either within the own national borders or in a neighbor country. Additionally, countries can use their investments to threaten each other to prevent or enforce certain actions by the other country. A schematic representation of the interactions of the countries in the model is shown in Figure 4.2.

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

1. National water consumption without exceeding actual water supply

2. Increase national water supply.

3. Invest into and collaborate on water supply in an upstream country to benefit from increased external supply.

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

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

5 Results of model simulations

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

We further assume that each country is willing to apply a certain maximum investment into water availability, which is a given percentage of GDP (4%) that is not to be exceeded. Investments into water resources are initialized on the basis of actual water consumption in each country. They then adjust to the self-defined water demands within the investment limits, as described above.

The water unit costs for the different action paths are selected to represent a situation, in which the unit costs for investing into increased water supply are considerably higher than the unit cost for water consumption, as long as the latter remains below the water supply. Domestic investment in Egypt is higher than in upstream countries, making it beneficial to also invest in upstream countries. Putting pressure on an upstream country has a low unit cost if the neighboring country accepts this pressure, but has the highest unit costs if this country resists, either by counter-pressure or by taking other non-cooperative action (including a possible military response).

Different scenarios are used in the computer simulation to assess the range of options from unilateral to conflicting and cooperative action. In selecting their action priorities, the countries can follow two guiding principles: individual rationality, e.g. by maximizing individual water availability, independent of other countries; or collective rationality, which takes into account the impact of a country's actions on the total water availability of other or even all countries. This represents the case of a coalition of water users. In addition to a reference scenario, we analyze two scenarios of climate change. In the first case, climate change reduces water availability in the Nile Basin by 20% by the end of the 20-year simulation period, in the second case there is an increase by 20% over the same time horizon.

Investments into obtaining additional water resources to satisfy the growing water demand is initially generally highest when the water becomes scarcer, i.e. if there is a negative climate impact (Fig. 5-1). Countries have to invest more money as there is less water that is naturally available to them. The particularly strong increase in total investments (that also include the costs for the actual consumption of the water) in Egypt in the scenario with a growing overall water availability has to do with the fact that the intended expansion of water availability in this country is particularly pronounced in this scenario. Given the already high consumption close to the supply limits, further expansion leads to a hike in the consumption costs which lead to this peculiar development of total investments.

Furthermore, the oscillations in the investments of Egypt into new water resources can be attributed to the fact that the country experiences switches between periods, in which their strategy of threatening upstream countries is resisted and those, in which the pressure is accepted by the other country (Fig. 5-1). Investment costs are much higher in phases of resistance, which diminish the incentive to threaten and increase incentives to cooperate. This leads to a cyclic switch between these two strategies, as given by the boundary case shown in Fig. 5-1. If the difference in costs between resistance and non-resistance were larger than in the case shown, the countries would refrain from threatening their neighbors as the strategy becomes too costly in the long run.

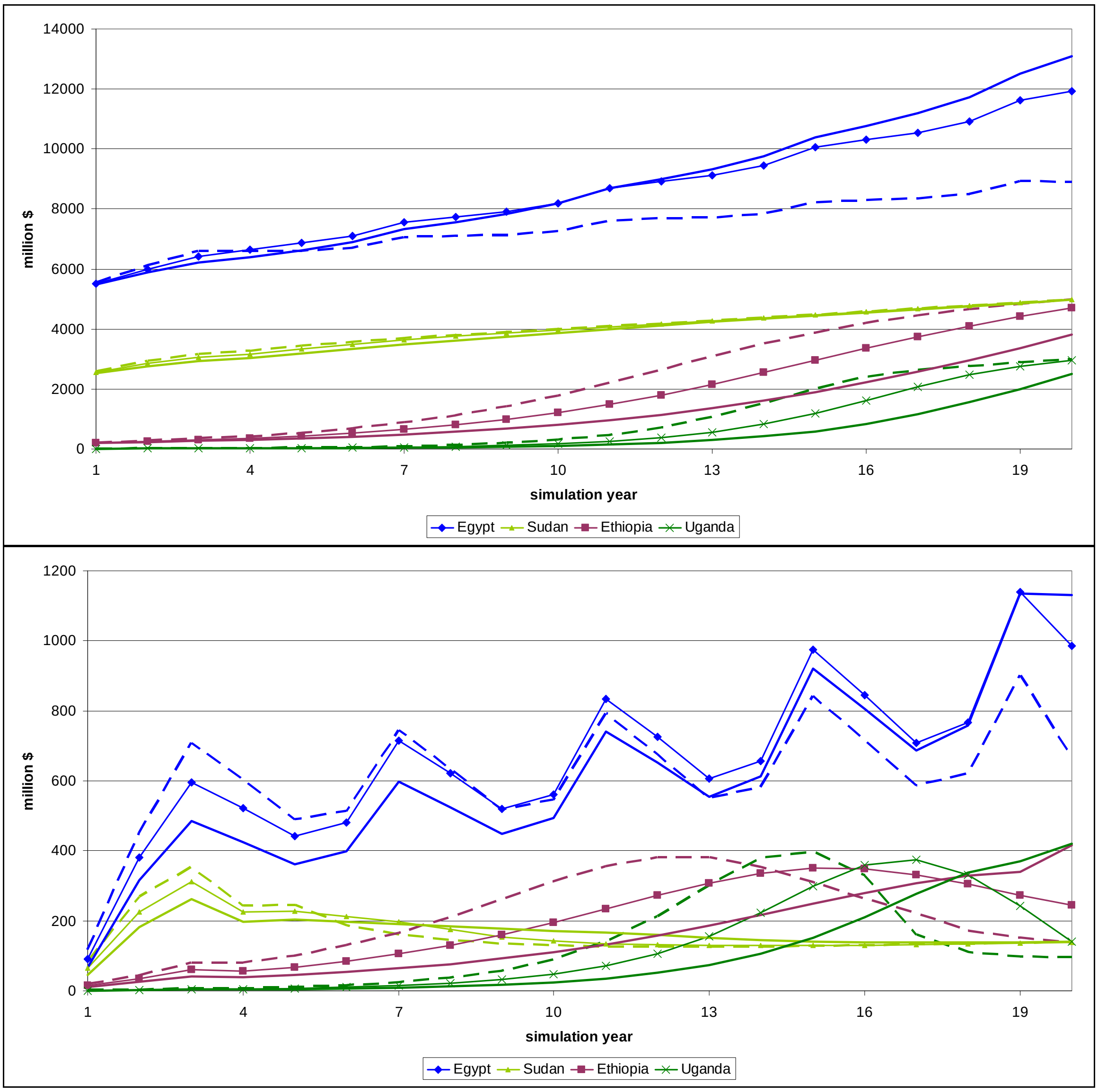

Figure 5.1 a-b: Development of the total investments into water resources (top) and investments into the acquisition of additional water resources (bottom). The thick solid lines denote the case of a climate change induced overall increase of water resources of 20% by the end of the simulation period, the dashed line a decrease of 20%. The lines with symbols denote a reference scenario with no climate change.

The development of the water supply in the countries considered in the model coincides with the climate scenarios (Fig. 5-2). Without any climate change influence, there is only a slight expansion of water supplies as investments are made into new sources. However, this strategy is quite expensive. The climate change influence dwarves these efforts, as the supplies grow considerably if there is more water available naturally and shrinks much more than can be offset by investments if water becomes scarcer as a consequence of climate change. In contrast, the consumption in the upstream countries Ethiopia and Uganda increases in all scenarios, with the increase occurring earlier if there is a trend towards overall lower water availability. Due to the water consumption goals that are considerably higher than the initial consumption in these countries, fair amounts need to be invested. These investments occur earlier and to a larger extent if a decline in water availability can be expected. In a country like Egypt, in which the water consumption close to the supply level throughout the simulation period, the negative development of overall water availability has an immediate effect on consumption despite all investment efforts to offset the effect of changing climate conditions.

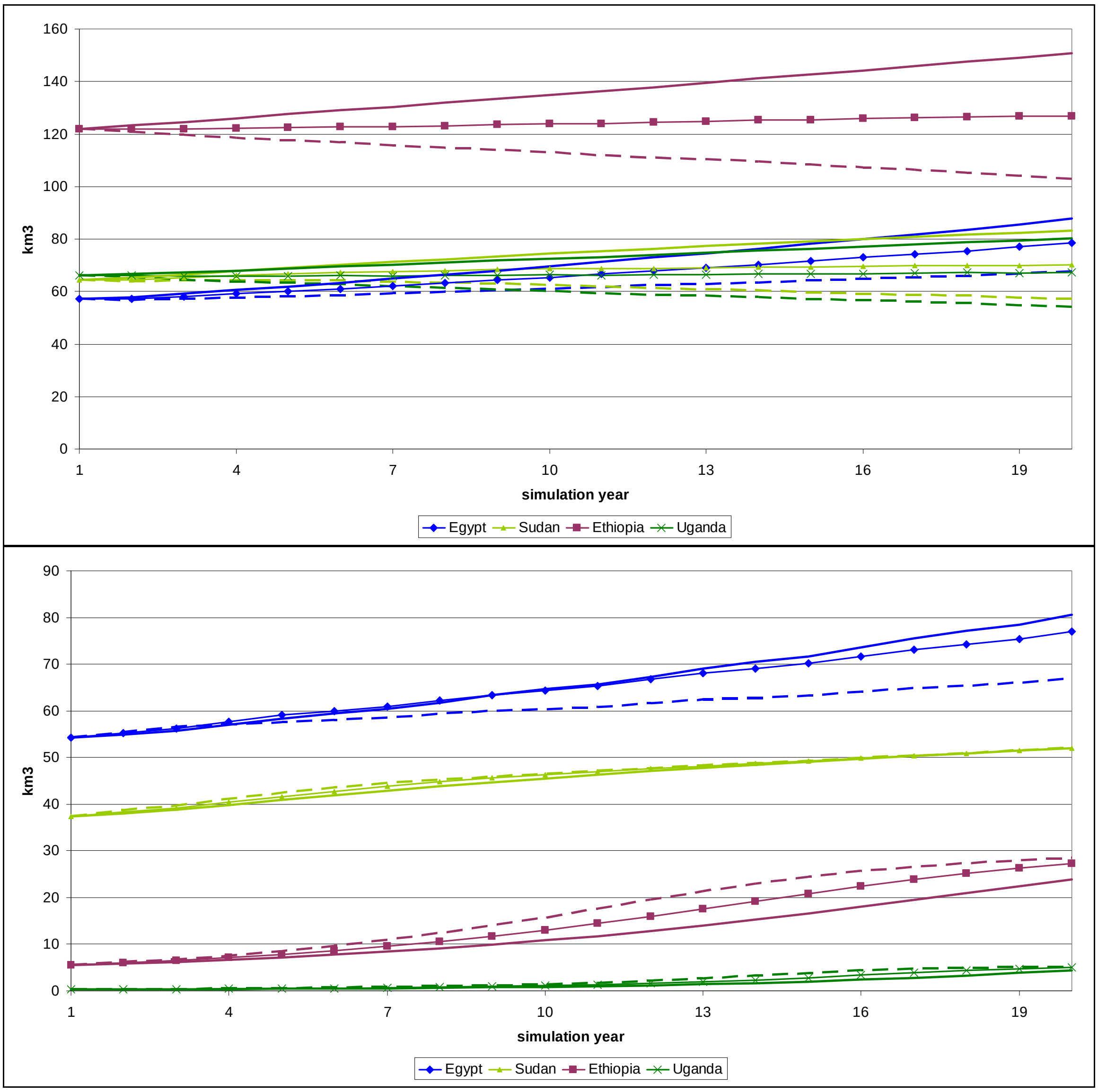

Figure 5.2 a-b: Development of the water supply (top) and water consumption (bottom) in each country. The thick solid lines denote the case of a climate change induced overall increase of water resources of 20% by the end of the simulation period, the dashed line a decrease of 20%. The lines with symbols denote a reference scenario with no climate change.

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

6 Discussion, conclusions and outlook

The potential impacts of climate change pose a number of risks to international security, such as a rise in the number of weak states, risks for economic development and international conflicts over resources. To address these challenges in a multilateral and cooperative way, the European Union has a record of dealing with environmental protection and promoting the concept of environmental security, both inside and outside the Euro-Mediterranean Partnership (Brauch, 2010). Yet the region suffers from a lack of cooperation between the various actors, and a number of Mediterranean dialogues coexist. The launch of a Mediterranean and Human Security Initiative (MED-SEC initiative) would allow a balanced economic co-development across the Mediterranean,
especially in the agricultural and energy sectors (Brauch, 2010).

Cooperative water management can make major contributions to preventing conflicts. A strong cooperation between Europe and the North African countries on water and food security, energy and climate security could be beneficial for the entire region, increase adaptive capacity, substantially contribute to emission reduction especially in the power sectors and create the preconditions for long term stability. A promising opportunity for strengthened North-South cooperation could be the vision of linking Europe to North Africa with electric power lines. Europe sees the possibility of producing a large quantity of electricity from renewable sources in North Africa to combat climate change, and to meet its emission reduction and renewable energy obligations. Furthermore, it attempts to decrease energy dependence and, at the same time, engage with a neighboring developing country region.

For North African countries it is important to develop opportunities of meeting the increasing local energy and water demand, to attract substantial foreign investments, generate export benefits and open the way to technology sharing, employment opportunities and economic desalination. Before new projects can be realized in the long run, a number of hurdles and criteria need to be addressed in the more immediate future.

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