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Nile water and agriculture

Past, present and future

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Key messages

- Agriculture has been a dominant feature of Nile Basin countries for centuries. Irrigated agricultural expansion over the last hundred years, often driven by foreign powers, has caused significant change in the use of the Nile water, and continues to be a major influence on the decisions around the Nile River use today.
- Use of Nile River water is a cause for transboundary cooperation and conflict. More than ever, the Nile Basin countries feel the pressure of expanding population requirements for food production and energy to develop their economies. However, historical treaties and practices continue to significantly shape directions of future Nile water use.
- Power development is changing the Nile River. Many dams are planned and several are under construction. The dam projects will have direct consequences for local populations and governments as they negotiate for water resources, land and power.

Introduction

This chapter highlights the use of the Nile River in the past and the present, and its future possibilities for both agriculture (crops, livestock and fish) and the economic benefit of the millions of people who live along the Nile. This brief glance at the geographical, historical and current developments of Nile water includes the socio-political, environmental and human consequences of these developments, and the direction towards which future changes in the Nile Basin might lead. Ultimately, the benefits of the Nile River need to be shared among the ten basin countries, with populations totalling approximately 180 million, of whom half are below the poverty line (Bastiaanssen and Perry, 2009).

Geographical Nile

A short introduction to the physical Nile will help to visualize the situation and understand the dynamics of historical and current power struggles. Figure 2.1 is used by the Nile Basin Initiative (NBI) and the Nile Equatorial Lakes Subsidiary Action Programme (NELSAP), and shows the areas and countries drained by the Nile River.

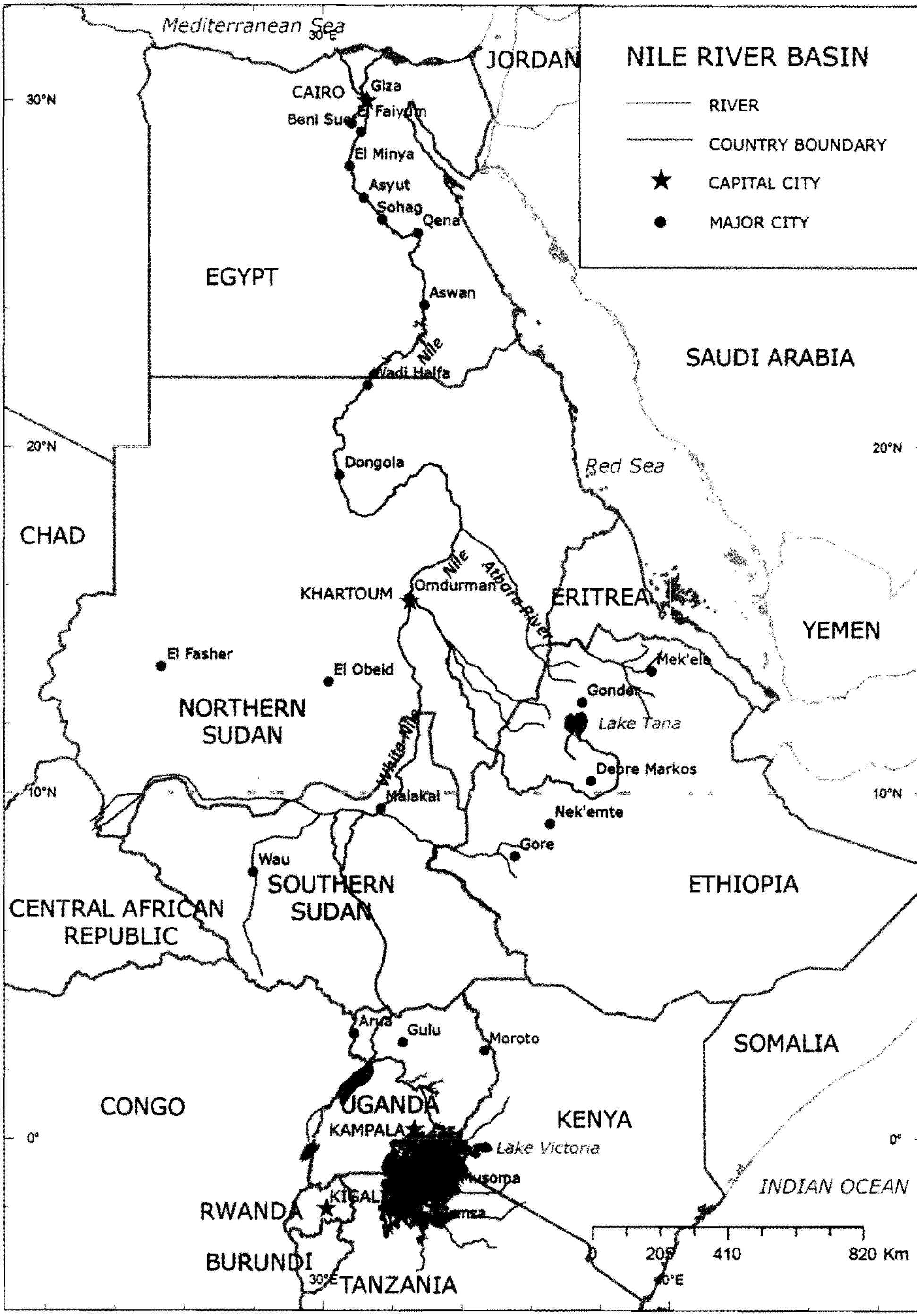

Figure 2.1 The Nile River Basin

Source: World Bank, 1998

The Nile River we know is quite different from the deep Eonile formed during the late Miocene period, 25 to 5.3 million years ago (mya), when the Mediterranean Sea dried up (Warren, 2006). The Cenozoic period of the Blue Nile was one of upheavals, plate movements and volcanic eruptions that occurred more than 30 mya, and this is what defines the hydrological differences between the Blue and White Niles (Talbot and Williams, 2009). The meeting of the Blue and White Niles is explained by two theories. Said (1981) believes that Egypt supplied most of the water to the early Nile, and the Nile we know now was formed within one of several basins more than 120,000 years ago – fairly recent in geological years. The other theory is of a Tertiary period river when the Ethiopian rivers flowed to the Mediterranean via the Egyptian Nile (Williams and Williams, 1980). Sedimentation studies and the discovery of an intercontinental rift system by Salama (1997) supports the Tertiary period Nile that formed a series of closed basins that connected during wet periods 120,000 years ago; the filling of the basins connected the Egyptian, Sudanese and Ethiopian Nile basins. The oldest part of the Nile drainage is associated with the Sudd, believed to have formed 65 mya. What we see of the Nile now is also in a state of change as the landscape is excavated to construct large dams to re-divert water and change the river's physiography.

The Nile River passes through several distinct climatic zones, is fed from different river sources, and creates vast wetlands, high surface evaporation and a huge amount of energy that is tapped for hydropower. Seventeen river basins feed into Lake Victoria, where John Speke identified the source of the Nile in 1862, with the greatest contribution from the Kagera River (Howell *et al.*, 1988).

The Nile is a river with many names. Exiting Lake Victoria, it is the Victoria Nile or White Nile; then, as it flows through Lakes Kyoga and Albert, it is called the Albert Nile; arriving in Sudan, the river is called Bahr el Jebel, or Mountain Nile; where it winds through the Sudd and flows into Lake No it is called the Bahr al Abyad, or White Nile, because of the white clay particles suspended in the water. Near Malakal the Ethiopian Sobat River joins the White Nile. Originating in Ethiopia, the Blue Nile born from volcanic divisions in the landscape that brought up the Ethiopian plateau has carved impressive gorges and brings silt-laden Blue Nile waters coiling around and collecting from many tributaries before flowing into the White Nile confluence at Omdurman Sudan, where the name becomes Nile or Main Nile. Further downstream, the Atbara River joins the Nile. The current Nile is supplied mainly from the Blue Nile called Abay in Ethiopia and fed by 18 tributaries. Contributions to the Main Nile from Ethiopian rivers are 86 per cent (composed of 59% from the Blue Nile, 13% from the Atbara and 14% from Sobat), all flowing into Egypt (Sutcliff and Parks, 1999). With this as background the history of the Nile will unfold.

Early Nile history

Before the common era

Ancient rock carvings in Egypt depicting cattle show that they have had a special importance within the Nile Valley cultures for thousands of years (Grimal, 1988). Pastoral production systems using wild cereals have been documented from the mid-Holocene period with evidence dating back to 10,000 BCE when the Nile Valley and the Sahara were one ecosystem. Early hunter, gatherer settlements have been documented in Nubian areas of Sudan dating to 9000 years back (Barich, 1998). Cave drawings from Ethiopia depicting sheep, goats and cattle date back to 3000 to 2000 BCE (Gozalbez and Cebrian, 2002). People at that time were in areas of unstable climatic conditions; they began herding to replace fishing as a primary

source of protein. Herding became a strategy aimed at reducing the effects of climate variations (Barich, 1998). Bantu-speaking people spread across the eastern and central areas of Africa over 4000 years ago. They were excellent pastoralists and farmers.

From 1000 BCE, agricultural patterns were established that remain characteristic to the present time. Ethiopian cultural and agrarian history is determined in part by its geography. The high plateau formed by volcanic uplifts is split by the African rift valley (Henze, 2000), where the Northern fringe of the rift constitutes the deepest and hottest land surface on Earth, 126 m below sea level (Wood and Guth, 2009). The origin of human beings had occurred in the split in the rift valley highlands; from here began the domestication of several economically important crops, such as coffee, teff, khat, ensete, sorghum and finger millet (Gozalbez and Cebrian, 2002). Vavilov (1940), a Russian plant palaeontologist studying the origins of ensete and teff, said the Ethiopian Highland region was one of the more distinctive centres of crop origin and diversification on the planet. In the 1920s, Vavilov found hundreds of endemic varieties of ancient wheat in an isolated area of Ethiopia.

Ethiopia, considered to be the cradle of humankind, was the site where anthropologists found early hominid remains from 3.18 mya (known as 'Lucy'; Johanson and Edey, 1990). From 8000 BCE fishers and gatherers settled along lakes and rivers. The earliest reference to Ethiopia was recorded in ancient Egypt in 3000 BCE, related to Punt or Yam, where the early Egyptians were trading for myrrh. Ethiopia was a kingdom for most of its early history, tracing its roots back to the second century BCE. Ethiopia's link with the Middle East is from Yemen on the Red Sea, thought to be the source of Yemeni migrants speaking a Semitic language related to Amharic, and bringing along animals and several grain crops (Diamond, 1997). Ethiopia has connections to the Mediterranean where its religious and cultural ties to the ancient cultures of Greece and Rome have played a role in its history.

In Egypt irrigated agriculture and control over Nile water have been continuous for more than 5000 years (Postel, 1999). Traces of ancient irrigation systems are also found in Nubia or North Sudan, where people grew emmer, barley and einkorn (a primitive type of wheat). The people who settled along the Nile River in the Pharaonic kingdoms were cultivating wheat, barley, flax and various vegetables. They raised fowl, cattle, sheep and goats, and fished. Irrigation was also practised in Sudan and Ethiopia thousands of years ago, but to a lesser extent than in Egypt. There are few, if any, ancient irrigation records from the upstream riparian countries of Burundi, Democratic Republic of Congo (DRC), Kenya, Rwanda, Tanzania and Uganda, but most have sufficient rainfall and still rely more on rain-fed than on irrigated agriculture.

There are many theories about the spread of farming in the Nile Valley, but the consensus is that people moved to the upper Nile River when the fertile plains of the Sahara began to dry up, forming deserts. The Nile River was too large to control in ancient times but irrigation came naturally with the annual Nile floodwaters, particularly in Egypt where early Egyptians practised basin irrigation (Cowen, 2007). Most of what is known about ancient irrigation practices was from the Pharaonic civilization in 4000 BCE, recorded in hieroglyphics where an ancient king was depicted cutting a ditch with a hoe to let water flow into the fields (Postel, 1999). The early Egyptians were linked to the Nile; they worshipped it, based their calendar on it, drank from it and lived in harmony with the alternating cycles of flow. It was the control of the yearly floods that allowed the Egyptians to irrigate using a system of dikes and basins. When the floodwaters receded water was lifted with a device called a *shadoof* to get it to where it was needed. Irrigation was so successful that Egypt was referred to as the breadbasket for the Roman Empire (Postel, 1999).

Egypt's dynastic periods were characterized by periods of advancement and stagnation. The Egyptians' attachment to the Nile River, land and ability to irrigate led to wealth and a strong

government, but this was followed by periods of stagnation in economy and population: 'It's not clear whether strong central government resulted in effective irrigation and good crop production, or whether strong central government broke down after climatic changes resulted in unstable agricultural production' (Cowen, 2007). Flooding periods came and went just as the ruling powers changed over and over again; in a period of decline the Assyrians took over (673–663 BCE), followed by the Persians (525 BCE), who were conquered by Alexander the Great in 332 BCE. Alexander the Great's death in 323 BCE signalled the start of the Ptolemaic dynasty; Cleopatra VII, last of the Ptolemaic rulers, took over and was subsequently defeated in 31 BCE, and the Roman Empire took over until the Arab conquest (El Khadi, 1998). Years of occupation of Egypt only added to and improved the irrigation systems.

Invaders and conquerors: the common era

From 300 to 800 CE, Bantu pastoralism helped shape the economy in the wet equatorial regions of Kenya, Tanzania and Uganda (Oliver and Fage, 1962). The trade and import of crops from the Far East further changed the influence of agriculture on the people in this region. From the settlements around the equatorial lakes many of these people grew and developed a trade in many crops, especially bananas. Cultivation of bananas and other crops was very successful in the wet equatorial region, and trade from cities in Kenya, Tanzania and Uganda developed rapidly.

Slaves were sought, used and exported from Uganda, Kenya, Tanzania and Uganda from the fifth century. Between the seventh and the fifteenth centuries, Arab slave traders introduced both Islam and slave trade to many regions in Africa, where they controlled the slave trade (Ehret, 2002). Arabic and Portuguese traders shaped the economy in East Africa, bringing in goods from China and India and trading them for ivory, gold and slaves.

Muslim armies also tried to enter Ethiopia in the 1540s, but unsuccessfully. Only later (in the 1850s) did Ethiopia begin to open up and interact more with foreign powers (Henze, 2000). Ruled for centuries by kings from the Solomonic Dynasty and isolated by its Coptic faith in a sea of Islam, Ethiopia was spared from conquests by foreign powers until the Italians caught up in the conquest for Africa invaded Ethiopia during 1936–1941 (Pankhurst, 1997; Henze, 2000).

For centuries, both Egypt and Sudan have viewed the Nile as their main lifeline, because they lacked other main freshwater sources. However, the dominant user of Nile water historically has been Egypt, which maintained its highly successful irrigation systems throughout the conquest periods – beginning with the Arab conquest in 641, followed by Turkish Mamelukes in 1250, until the Ottomans took over in 1517. The Arabs realized how important the Nile was to the success of their control over Egypt (El Khadi, 1998). It was the Arabs that made improvements in the irrigation practices with new types of water-lifting devices, building embankments and canals, and monitoring the Nile flow with about 20 Nilometers (devices that allowed them to measure river levels, compare flow over years and predict the oncoming floods). While the Mamelukes were warriors with periods of fighting, they were also builders, as evidenced by several beautiful mosques in Cairo. Their main agrarian successes were in land tenure and property rights, which also had an effect on land productivity (El Khadi, 1998).

The Ottomans took over in 1517 and were defeated in 1805. The Ottomans did not change irrigation much, but they did keep detailed records. The Ottomans were also very attentive to the Nilometer because it determined the health of the country, predicting floods, which meant how much tax the Ottomans would put on the Egyptian farmers. The French, under Napoleon, attacked Cairo in 1798 and defeated the Mamelukes at the battle of the pyramids;

during the attack they partially destroyed the Nilometer at Roda. In a costly expedition to Egypt in 1798, Napoleon wrote:

> There is no country in the world where the government controls more closely, by means of the Nile, the life of the people. Under a good administration the Nile gains on the desert, under a bad one the desert gains on the Nile.
>
> *(Moorehead, 1983)*

To obtain peace with the Egyptians again, they rebuilt the Nilometer. Mohamed Ali Pasha finally drove the Mamelukes and the Ottomans from Egypt.

When Mohamed Ali Pasha took control of both Egypt and Northern Sudan in 1805 there was an active period of agricultural expansion, increased irrigation and excavation of more canals. Mohamed Ali's polices gave priority to agricultural production, and yields of cotton and other crops were boosted by year-round irrigation. Mohammed Ali established the first agricultural school in 1829. This school closed and reopened several times in several locations; education has been a high priority for Egyptians (IDRC and MoA, 1983). Later, Mohammed Ali, with help from French engineers, began the construction of two barrages at the Damietta and Rosetta branches to control water going into the delta (El Khadi, 1998).

Colonial past and control of the Nile

Beginning in the early 1700s and continuing to the late 1800s, Europeans began to realize the importance of understanding the Nile River, where it came from, how much water there was and how to control it. Finding the source of the Nile was a necessary step needed to make treaties and 'legalize' the use of Nile waters. The English, because they had much to gain, were very central to most of the actions taken on the White Nile, mapping, measuring, clearing canals for navigation in the Sudd and allocating water. Scientific measurements of Nile flow began in the early 1900s with the installation of modern meters along the Nile (Hurst *et al.*, 1933).

Explorations by Europeans on the upstream sections of the Nile began mainly during the period 1770–1874. A Portuguese monk who founded a Catholic church at Lake Tana is believed to be the first European to note the Blue Nile source in Ethiopia in 1613 (Gozalbez and Cebrian, 2002). The length of the main Nile River, plus the physical dangers of passing through cataracts and the swamps in southern Sudan, gave explorers trouble for many years. The White Nile source caused confusion and acrimony between Richard Burton and John Speke, and it was 1862 when John Speke's claim was confirmed that the river flowed out of Lake Victoria through Rippon Falls. Grant and Speke would also follow the flow to Lakes Kyoga and Albert, and on to Bahr el Jebel. Europeans began vigorous scientific explorations, making maps and hydrological measurements. In 1937 a German scientist explorer named Dr Burkhart Waldecker traced the Kagera River to its southern-most source, with its headwaters in Burundi. In 2006, a National Geographic group of explorers have claimed to be the first to travel the length of the Nile to its true source in Rwanda's Nyungwe Forest (Lovgren, 2006). Using modern geographic information system (GIS) equipment they believe they have accurately identified the source. To ease the confusion, the National Geographic Society has in the past recognized two sources of the Nile, one in Rwanda and one in Burundi.

Several foreign powers were involved in shaping the history of the southern Nile nations. The United Kingdom, Germany and Belgium were all colonial power players in Kenya, Rwanda, Tanzania and Uganda. They brought diseases that are estimated to have killed off

40–50 per cent of the population in Burundi. The colonialists were interested in large plantations for growing sugar cane and cotton to send back to Europe.

In 1888, the Imperial British East African Company was given administrative control over all of east Africa. The Ugandan leader signed a treaty of friendship with the Germans in 1890, but in 1894 the British quickly made Kenya and Uganda protectorates. An Anglo-German agreement put Burundi, Rwanda and Tanganyika into German control. The United Kingdom's reason for wanting Kenya and Uganda was to protect their interests on the Nile in Egypt and Sudan.

Because of Egypt's total dependence on the Nile River, Egypt continued to develop more control, making embankments and creating more structures. The first structure was a diversion dam called the delta barrage, which was built across the Nile north of Cairo, where the delta begins to spread to raise the water level for upstream irrigation and for navigation on the river. The barrage was completed in 1861 after rebuilding and improving the structure. The main purpose of the dam was to improve irrigation and expand the agricultural area in the delta.

In 1890, Ethiopia was the only independent country in Africa. British influence was responsible for the allocation of Nile water, beginning in 1890 with a treaty, the Anglo-German Agreement, between Great Britain and Germany, which put the Nile under Great Britain's influence (Tvedt, 2004). The following year, Great Britain signed a protocol with Italy when they held interests in the Blue Nile region of Eritrea in which Italy pledged not to undertake any irrigation work which might significantly affect the flows of the Atbara into the Nile (Abraham, 2004). Anglo-French control over Egypt ended with outright British occupation in 1892. With these agreements Great Britain secured control of the Nile, and occupied Egypt to watch over its interests in the Suez Canal and to grow cotton for its textile mills. In 1898, the British took over Sudan and established cotton as a major export crop.

The British were fairly secure in their control over the Nile River, but there were threats from other European powers. In the middle of the nineteenth century Italy had colonized the area of Eritrea, and they wanted more of Ethiopia. Italy's show of power in Ethiopia and Eritrea was supported by Britain hoping to squash the Mahdist threat in Sudan; on the other side, the French were supporting King Menelik's opposition to the Italians to back their own interests (Ofcansky and Berry, 1991). King Menelik's weakening health and control over the country alerted Britain, France and Italy and to avoid a more serious situation in the region; the three negotiated an agreement that later became known as the Tripartite Agreement of 1906 (Keefer, 1981).

In 1902, the British formed the Nile Project Commission, with expansive development plans for projects on the Nile River. The plans included dams on the Sudan/Uganda border, the Sennar for irrigation in Sudan and one to control the summer flooding in Egypt. Egypt disliked these plans. Control over Nile water by the British was the same as control over Egypt. By 1925, a new water commission made acceptable for development plans led to the 1929 water agreement between Egypt and Sudan. Great Britain sponsored the 1929 agreement that gave 4 billion cubic metres per year (m^3 yr^{-1}) to Sudan, and the rest of the yearly flow from January to July, plus 48 billion m^3 yr^{-1} to Egypt. The most important statement in the agreement for Egypt was 'Being guaranteed that no works would be developed along the river or on any of its territory, which would threaten Egyptian interests.' According to Wolf and Newton (2007), 'The core question of historic versus sovereign water rights is complicated by the technical question of where the river ought best be controlled – upstream or down.'

A committee of international engineers in Egypt built the first true dam on the Nile; the Aswan Low Dam was completed in 1902 at the time of the first signing of treaties. The dam was raised several times, and as irrigation demands increased and floods threatened it was raised

once more in 1929. Extensive measurements and studies made it clear that another dam was needed after the near overflow of the low dam in 1946. The main reason for building the Aswan High Dam (AHD) was to control the flow of water and to protect Egypt from both drought and floods. This allowed Egypt to expand irrigated agriculture and supply water to attract industries (Abu-Zeid, 1989; Abu-Zeid and El-Shibini, 1997). The British and Americans originally agreed to fund the AHD under Nasser, but the funding was suddenly halted just before construction began due to the Cold War and Arab/Israeli tensions in the region (Dougherty, 1959). The Soviet Union agreed to assist the construction and funding to help complete the project with the Egyptians.

Unhappy with plans for the AHD, Sudan demanded that the 1929 treaty be renegotiated. Great Britain was involved in all Nile water concessions until 1959 when Egypt and Sudan signed a bilateral agreement to allocate Nile water between the two countries. Egypt did not bother to consult or include upstream riparians, except Sudan in the reallocation of Nile water (Arsano, 1997; Abraham, 2002). This 1959 agreement set the maximum amount of water that could be withdrawn by these two countries with Egypt getting 55.5 billion m^3 out of a total average flow of 84 billion $m^3\ yr^{-1}$, allowing 10 billion $m^3\ yr^{-1}$ for evaporation and 18.5 billion $m^3\ yr^{-1}$ to Sudan.

They also had a growing demand for irrigation and energy for their expanding population. A section of the 1929 treaty was integral to the 1959 agreement, which said 'Without the consent of the Egyptian government, no irrigation or hydroelectric works can be established on the tributaries of the Nile or their lakes if such works can cause a drop in water level harmful to Egypt' (Carroll, 2000). This guaranteed Egypt a set amount of Nile water, which could not be changed. This agreement included a pact to begin construction of the AHD in Egypt, and Roseires Dam and the Jonglei Canal in Sudan with benefits to be gained by Egypt and northern Sudan.

Post-colonial Nile

Many African countries gained their independence from colonial powers in the late1950s and early 1960s. The return to African rule was difficult after the colonizing powers had realigned borders and tribal ethnic groups. This was particularly true in the equatorial countries of Burundi, Rwanda and Uganda. The negotiations that took place between Great Britain and Egypt were not as important in Burundi, where they have enough rainfall; but neither did they feel obligated to acknowledge the accords that were made prior to independence. The equatorial countries (Burundi, DRC, Kenya, Rwanda, Uganda and Tanzania) agree that agreements prior to independence were no longer valid. Only the post-independence agreement in 1959 between Egypt and Sudan, which did not include any of the equatorial countries, can be disputed.

Once the agreement between Egypt and Sudan was signed in 1959, work began on the second Aswan Dam. The construction began in 1960 after moving ancient temples and a large Nubian population, and was completed in 1970. There were complications, including increased salinity and reduced fertility, but also many benefits, of which power was the most important for the development of Egypt (Abu-Zeid and El-Shibini, 1997; Abu Zeid, 1998; Biswas, 2002).

In 1964, while the negotiations were going on between Egypt and Sudan, Ethiopia had employed the United States Bureau of Reclamation (USBR) to study the hydrology of the upper Blue Nile Basin (US Dept of Interior, 1964). The study identified potential new irrigation and hydroelectric projects within Ethiopia. Preliminary designs for four large dams were prepared for both the Blue Nile and Atbara rivers that would increase power production by

5570 megawatts (MW). Block *et al.* (2007) took a renewed look at the USBR study using a model that shows little benefit/cost ratios for the use of both hydropower and irrigation for agriculture due to limitations in timely water delivery. Recent climate change studies by Block and Strzebek (2010) present a cost/benefit analysis giving several climate change scenarios that report favourable results for water conservation behind the dams in Ethiopia, but less favourable results given that success of the dams, purpose of hydropower and irrigation will depend greatly on the timing of water, climate variability and climate change. They emphasize close cooperation and economic planning that secure energy trade between neighbouring countries.

Waters of the Nile have been used for centuries for irrigation in Sudan, taking advantage of the annual Nile flood that builds up from heavy summer rains on the Ethiopian plateau. When the world market was in need of cotton it became Sudan's first commercial crop. The Sennar Dam, funded and built by the British just south of Khartoum in 1918, was to supply water to irrigate 126,000 ha of cotton in Gezira to supply British textile mills. But by the 1950s more land was needed; indeed, it had to double, and irrigation water was not enough (Wallach, 2004). Sudan needed the 1959 agreement mentioned above to increase its allotment of Nile water and to proceed with building the Roseires Dam on the Blue Nile, which was completed in 1966 to improve irrigated agriculture and to supply hydropower. Approximately 800,000 ha yr^{-1} were irrigated in the Gezira scheme by the end of the 1960s.

Until 1959, treaties were geared towards allocation of Nile water resources for irrigation. The 1929 and 1959 treaties were meant to secure irrigation water for the Gezira scheme in Sudan and Egypt, respectively. However, after 1959, and following independence of other Nile basin states, the focus of Nile agreements shifted away from water-sharing to more cooperative frameworks. As a consequence, irrigation water demand was overlooked in favour of Nile negotiations, and power supply took over (Martens, 2009).

The 1959 treaty left a legacy for potential conflict between Egypt and Sudan, on one side, and Ethiopia and the seven other riparian countries, on the other. Experts who have analysed the 1997 United Nations Watercourses Convention say it cannot resolve the legal issues concerning allocation of Nile water (Shinn, 2006). Egypt says that all Nile countries must recognize the 1959 treaty before any new agreements are implemented, including benefit-sharing proposals. This is not negotiable, according to Egypt; this claim has not been favoured by the rest of the riparian countries (Wolf and Newton, 2007). The issue becomes more complex, as several upstream riparian countries have recently criticized the 1959 treaty. Several riparian nations, especially Ethiopia, state that (i) they were not included in the 1929 and 1959 treaties and (ii) these treaties violate their right to equitable utilization as stated in the 1997 UN convention. The upstream countries with their own development issues do not feel that they need Egyptian permission to use Nile water. Attempts to unite the Nile Basin countries led to the development of the NBI.

The NBI was formed in 1999 to 'cooperatively develop the Nile and share the benefits, develop the river in a cooperative manner, share substantial socio-economic benefits and promote regional peace and security' (NBI, 2001). Funded by several donors, including the World Bank, the NBI is headed by a council of ministers of water affairs, comprising nine permanent members and one observer, Eritrea. In May 2010, Ethiopia, Kenya, Rwanda, Uganda and Tanzania signed a Cooperative Framework Agreement (CFA) to equitably share the Nile waters. Later, Burundi and the DRC also signed the CFA. Meantime, and due to lack of agreement between the different parties, a proposal emerged to rephrase Article 14b to include the ambiguous term 'water security' in order to accommodate and harmonize the differing claims of the upstream and downstream riparian countries (Cascão, 2008). Egypt refused to sign the CFA if the change in Article 14b on 'benefit sharing' was not made and has

threatened to back out of the NBI if all the other countries sign the agreement. Arsano (1997) believes the NBI has been able to bring the riparian states on board for dialogue towards establishing plans for cooperative utilization and management of the water resources, and to make an effort towards establishing a legal/institutional framework.

The NBI has been instrumental in promoting information-sharing and initiating small projects, but it is still struggling to be a permanent river organization, to obtain signatories for the ratification for a new Nile Treaty as agreed by all members and to implement new large Nile Water projects (Cascão, 2008). Criticism has been aimed at a lack of coordination in development activities between the NBI and the governments of the Nile Basin countries. Basin-wide collaboration has, as Bulto (2009) states, 'hit a temporary glitch, casting doubt over the prospect of reaching a final framework agreement over the consumptive use of Nile waters'.

Recent agricultural expansion

Except for Egypt and Sudan (who have a longer history of irrigation and control of the Nile water), the other Nile Basin countries have relied more on rain-fed agricultural potential for their available water resources. Some reasons include limited financial resources, infrastructure, governance and civil wars. Increasing populations in the riparian countries mean a greater demand for food, water and energy. Poverty has led some countries to sell land to foreign buyers in hope of developing agricultural infrastructure and bringing jobs and money into areas of extreme poverty (IFPRI, 2009). Since 2008 Saudi investors have bought heavily in Egypt, Ethiopia, Kenya and Sudan (BBC, 2010; Vidal, 2010; Deng, 2011).

The Egyptian government has built over 30,300 km of channels and large canals in Egypt (El Gamal, 1999). Egypt has used desert lands to expand cultivation of horticultural crops such as fruits, nuts, vineyards and vegetables. Reclamation of desert lands allows Egypt to expand production and use drip irrigation from groundwater reserves. The use of drip irrigation and plastic greenhouses has increased attempts to save water. These are more expensive for the traditional farmers, but many investors have put these to use and have successfully supplied produce to the local markets.

Aquaculture in the Nile Delta is booming, and demonstrates high water productivity while using drainage water flows. Aquaculture in Egypt's Delta makes use of recycled water and also shows promise of providing an important source of dietary protein and income generation. Aquaculture has rapidly expanded, and yields have grown from 20,000 tonnes in the 1980s to more than 600,000 tonnes in 2009, due to run-off from sewage and fertilizer-enriched water (Oczkowski *et al.*, 2009).

Egypt's plan to develop the North Sinai Desert is a huge land reclamation project, estimated to cost nearly US$2 billion when completed. From October 1997 the Al-Salam Canal was delivering water to irrigate about 20,200 ha of the Tina Plain, which is actually outside the natural course of the Nile. The north Sinai agriculture development project is planned to eventually divert 4.45 billion m^3 yr^{-1} of Nile water to develop irrigated agriculture west and east of the Suez Canal. The 261 km-long Al-Salam Canal is the summation of both first and second phases. The Al-Salam Canal runs eastwards, taking Nile water horizontally across the Sinai. The second phase extends further east, passing under the Suez Canal to open nearly 168,000 ha of irrigated agricultural lands; both phases require a 1:1 mix of Nile water with drain water, keeping salinity and pollutants at a minimum (Mustafa *et al.*, 2007).

According to several reports, Ethiopia has about 3.7 million ha that can be developed for irrigation; about half of this is in the Nile Basin, but only 5–6 per cent has been developed so far (Awulachew *et al.*, 2007, 2009). Their current irrigated area is about 250,000 ha, with less than

20,000 ha in the Nile Basin; most of the current agricultural production is rain-fed. Ethiopia plans to expand agricultural production by an additional 3 million ha with the addition of many small- and large-scale irrigation schemes, both private and government-funded, and distributed in various parts of the country. Water for the schemes will come from several new multi-purpose hydropower projects that are completed and planned for future development.

Sudan developed two schemes in the 1960s that proved untenable and too expensive to complete (Wallach, 2004). The scheme at Rahad was intended to use water from the Roseires Dam in 1960 but lacked financial resources to develop canals. It was delayed, and finally one-tenth was operational in 1978. It is a 122,000 ha scheme irrigated from the Rahad River, using Blue Nile water; it is plagued by siltation and irrigation inefficiency, and yields have been below average (Wallach, 2004). New Halfa built to use water from the Khashim el Girba Dam was basically a resettlement scheme for Halfawis people who lost land and homes when Lake Nasser was filled. The Khashim el Girba Dam built for the Halfa scheme silted too quickly and was poorly planned (El Arifi, 1988). These two schemes were good lessons for the planners, forcing them to consider rehabilitation of existing schemes. Wallach (2004) describes the challenges of rehabilitation and modernization of irrigated agriculture in Sudan.

In the 1990s Sudan had a 2 million ha modern irrigation system developed in a fertile valley south of Khartoum between the Blue and White Niles. More than 93 per cent was government-managed. This area was originally the Gezira scheme started by the British in the 1920s. When the Nile agreement with Egypt was signed in 1959 the area was expanded to the west. Cotton is a mandatory crop, but in the 1970s cotton was partly replaced by sugar cane. Generally, yields are poor, partly due to government policies, poor canal maintenance, lack of irrigation water and inefficient use of water (Molden *et al.*, 2011).

Water, land, food, energy and development are tightly and crucially interlinked. Water is also very much linked to the potential for peace in the region. Dialogue between the riparians is necessary for the area to solve water-sharing issues. Rehabilitation of irrigation systems, improved water management including rain-fed agriculture and policy reforms will help improve existing agricultural performance.

Nile environmental challenges: wetlands, lakes and Blue Nile

The Sudd

Large wetlands forming about 6 per cent of the basin area are found in eight of the Nile Basin countries. The largest and the most important wetland to the hydraulics of the downstream Nile River is the Sudd (meaning 'blockage'), located in South Sudan (Sutcliff and Parks, 1999). The Sudd is an extensive area (average 30,000 km^2) of mainly papyrus swamp legendary for being impenetrable, high in biodiversity, having high evaporation and transpiration rates, and more recently oil and conflict.

More than 50 per cent of the water that flows into the Sudd and circulates within its ecosystems evaporates; thus, less than half of the water flowing into the Sudd actually flows out again to continue north to Khartoum (Sutcliffe and Parks, 1999). Estimates of inflow to outflow ratios vary, as do the size and evaporation rates; for example, Mohamed *et al.* (2004) estimate 38.4 billion m^3 yr^{-1}, and Sutcliff and Parks (1999) estimate 16.1 billion m^3 yr^{-1}. Reasons for different values include different means of calculation, as well as different times of measurement. Satellite images have helped improve information on the Sudd. Mohamed *et al.* (2006) have found that the swamps are larger than previously thought and the fluctuation in evaporation is difficult to estimate due to the size, and estimated the evaporation at 29 billion m^3 yr^{-1}.

From the early 1900s, British engineers began to think of creating a canal through the swamps in South Sudan (Howell *et al.*, 1988). Their concern over high rates of evaporation from the swamps prompted the development of the Jonglei Canal to channel water out of the swamps and send it north for the benefit of agricultural production in North Sudan and Egypt. In the 1980s, a large digging machine from France was brought to begin the canal. Scheduled for completion in 1985, the still incomplete canal, due to its size (80 m wide, 8 m deep and roughly 245 km long), is visible from satellite images (NASA, 1985). Work on the canal was abruptly stopped during the civil war in 1983.

The Jonglei Canal was supposed to bring about 5–7 per cent more water to irrigation schemes of both Egypt and Sudan. Egypt and Sudan have been in discussions to revive the project, but without the consent of southern Sudan this will not be possible (Allen, 2010). However, the social-environmental issues of drying wetlands, loss of traditional grazing lands, biodiversity and collapse of fisheries are reasons given to discontinue the canal (Ahmad, 2008; Lamberts, 2009). Counter-arguments state that the drying wetlands will create new grazing lands and the canal can be used for fisheries (Howell *et al.*, 1988). Furthermore, the consequences of draining the wetland on the larger regional and micro-climatic conditions are difficult to predict. Meanwhile, southern Sudan and the Sudd area have vast potential for development and improvement of agriculture with large areas of land suitable for mechanized farming (UNEP, 2007).

Oil development is an added threat to both the ecosystem and human communities. Oil drilling conducted by foreign companies brings in workers from outside of Sudan, providing very little benefit to the local communities. Conflicts arise over loss of grazing lands, loss of traditional livelihoods and increases in diseases (e.g. AIDS/HIV). Damages to the human communities, wetlands and ecosystems need monitoring and responsible management for future generations (UNEP, 2008).

The Sudd possesses huge potential for enhancing the livelihoods of local inhabitants through development of improved agriculture, pasturelands and fisheries, while supporting a rich ecosystem, and water resources. Controversy continues over the decision to finish the Jonglei Canal or abandon it. At present, it remains to be seen what the newly formed government of South Sudan will decide.

Victoria Nile

The outflow at Jinja, which was once thought to be the source of the White Nile, is a determinate point for measuring Nile flow from the lake. Nearly 80 per cent of the water entering Lake Victoria is from precipitation on the lake surface, and the remainder is from rivers, which drain the surrounding basin (Howell *et al.*, 1988). Some 85 per cent of water leaving the lake does so through direct evaporation from its surface, and the remaining 15 per cent leaves the lake near Jinja in Uganda, largely by way of the Victoria Nile. Three countries – Kenya (6%), Tanzania (51%) and Uganda (43%) – share the lake shoreline, and six countries share the basin: Burundi, DRC, Kenya, Rwanda, Tanzania and Uganda. The area around Lake Victoria has the fastest-growing population in East Africa, estimated to be more than 30 million in 2011 (LVBC, 2011).

In the 1940s Nile perch were introduced to boost fisheries production, which had already begun to fall. Nile perch depleted the endemic species and hundreds became extinct. Recently, Nile perch populations have dropped due to overfishing allowing some remaining endemics to make a slow comeback (Hughes, 1986). Lake Victoria produces a catch of over 800,000 tons of fish annually, an export industry worth US$250 million (LVFO, 2011).

Lake Victoria is important for agriculture, industry, domestic water supplies, hydropower, fisheries, travel, tourism, health and environment. It is highly sensitive to climate change and climate variability. The shallow lake is threatened by sewage, industrial and agricultural pollution, algal growth, overfishing, invasive flora and fauna, low water levels and deforestation (Kull, 2006; Johnson, 2009). Many of the biological effects directly affect the socio-economic factors of the people living on, and supported by, Lake Victoria fisheries (Onyango, 2003).

Dropping water levels have caused alarm in many of the downstream countries. Kull (2006) estimated that in the past two years, the Ugandan dams have released water at an average of almost 1250 m^3 sec^{-1}; that is 55 per cent more than the flow permitted for the relevant water levels. Diminishing water levels have acute consequences for several economic sectors dependent on the lake, such as fisheries and navigation. Variations in the water level affect shallow waters and coastal areas, which are of particular importance for numerous fish species and health of the lake. The largest projected climate change for rainfall and temperature changes for the interior of East Africa is over the Lake Victoria Basin (Conway, 2011).

Some of the greatest concerns for management are related to reducing vulnerability and poverty and improving livelihoods of the people living beside Lake Victoria. Coping with climate change effects on Lake Victoria requires a range of strategies, including proactive measures to improve the health of Lake Victoria and a reduction of the dependency on Nile perch exports (Johnson, 2009). Victoria Basin countries and organizations need to address all the factors that affect the watershed and the lake. The Lake Victoria Basin Commission (LVBC) was formed with the East African Community (EAC) to develop strategic plans for the basin countries to sustainably develop and protect the lake from further destruction (LVBC, 2011).

Blue Nile

Most of the main Nile flow can be explained by rainfall variability in both Lake Victoria and the Blue Nile Basin (Conway, 2005). The upper Blue Nile Basin is the largest section of the Nile Basin in terms of volume of discharge and second largest in terms of area in Ethiopia and is the largest tributary of the Main Nile. It comprises 17 per cent of the area of Ethiopia, where it is known as the Abay, and has a mean annual discharge of 48.5 billion m^3 (1912–1997; 1536 m^3 s^{-1}; Hughes and Hughes, 1992), with variation from less than 30 billion m^3 to more than 70 billion m^3, according to Awulachew *et al.* (2007).

This part of the sub-basin is characterized by a highly seasonal rainfall pattern, most of the rain falling in four months (June to September), with a peak in July or August. Soil erosion is a major threat in the Blue Nile Basin (Conway and Hulme, 1993). A report prepared by ENTRO (2006) estimates the total soil eroded within the Abay Basin alone is nearly 302.8 million tonnes per annum (t yr^{-1}) and erosion from cultivated land is estimated to be 101.8 million t yr^{-1} (33%). Thus about 66 per cent of soil being eroded is from non-cultivated land, (i.e. mainly from communal grazing and settlement areas; Molden *et al.*, 2011). About 45 per cent of this reaches the stream system annually causing heavy siltation of downstream reservoirs.

The Nile's ecosystems are threatened by many human activities, but by far the most damaging are agricultural practices. Good agricultural practices to control erosion, pollution and land degradation can enhance other ecosystem services. From Lake Victoria, the Sudd's and the Blue Nile's control over pollution, overgrazing, mining and erosion will help good governance, policies and organizations that could, in turn, help in regulating and monitoring the ecosystems.

Recent irrigation developments

WaterWatch (2008) estimates that the total irrigated area in the Nile Basin is 4.3 million ha, based on GIS measurements. Irrigated agriculture in the basin is dominated by Egypt, with 35 milion ha, while Sudan has 1.8 million ha and Ethiopia 0.3 million ha (CIA, 2011). Egypt and Sudan are almost completely dependent on Nile water for irrigated agriculture. Sudan's arable land is estimated to be 105 million ha, with about 18 million ha under cultivation, most of the latter being rain-fed. Sudan now irrigates about 1 per cent of its arable land.

Huge new irrigation projects in Egypt and Sudan are being planned and executed. Egypt's Al-Salam Canal, some parts of which are built under the Suez Canal, diverts Nile water and drains water from the Damietta Canal to irrigate land in northern Sinai, which will require 4.45 billion m^3 yr^{-1}. The Toshka Lakes were formed in 1997 when Egypt developed pumping stations and canals to send 'excess' Nile water into a depression in the southwest desert about 300 km west from Lake Nasser. Named the New Valley Project, if complete in 2020, it will require an additional 5 billion m^3 yr^{-1} of water, be home to 3 million people and irrigate 25,000 m^3 ha^{-1}. This expansion is to be sustained by transferred water but it could mean disaster in the future if there is no spill water available to send to the lakes.

Upstream Nile countries, dependent on rainfall, have experienced a greater frequency of droughts and cannot ignore the need to grow more food and expand production even at great costs; this requires irrigation. Ready to claim its share of Nile water, Tanzania is planning to build a pipeline 170 km long that will take water from Lake Victoria south to the Kahama irrigation project in an arid poverty-stricken area where thousands of people will benefit. Other upstream Nile countries also feeling more confident and pressed to find solutions to fight hunger and poverty will try to use their 'share' of Nile water and are planning to build multi-purpose hydropower dams.

Increasing climate variability, population growth, food prices and vulnerability to food shortages mean that larger, wealthier countries need to look elsewhere to buy or produce more food. How can they produce more when all their arable land is currently cultivated or they lack the resources to produce more food?

Power on the Nile: past and future

Many of the Nile Basin countries are classified as some of the poorest in the world in terms of GDP and food security (FAO, 2010). Most people lack electrical power and the necessary means of obtaining electricity; average electrification rate is 30 per cent (per capita per annum) and this drops to 15 per cent when Egypt and DRC are excluded. This is a very low proportion, according to Economic Consulting Associates (2009). Hydropower is underexploited in most of the basin countries affecting growth and development. Deforestation for charcoal production in the Lake Victoria Basin is one example of the need to produce affordable power for people in the area. Hydropower dams and the generated power offer other benefits that include additional irrigation water, controlled releases, water storage and further social and industrial development. Figure 2.2 shows the placement of early dams on the Nile (Nicol, 2003).

Aswan High Dam (AHD), completed in 1970, is the largest man-made reservoir and produces 2100 megawatts (MW) of electricity – about half of Egypt's total power supply. It was planned to resolve both floods and droughts and irrigate about 283,000 ha. At the time, only Sudan was consulted before the AHD was built. Now other Nile countries will build more dams on the Nile (Table 2.1). Egypt feels that they should give permission for any developments on the Nile.

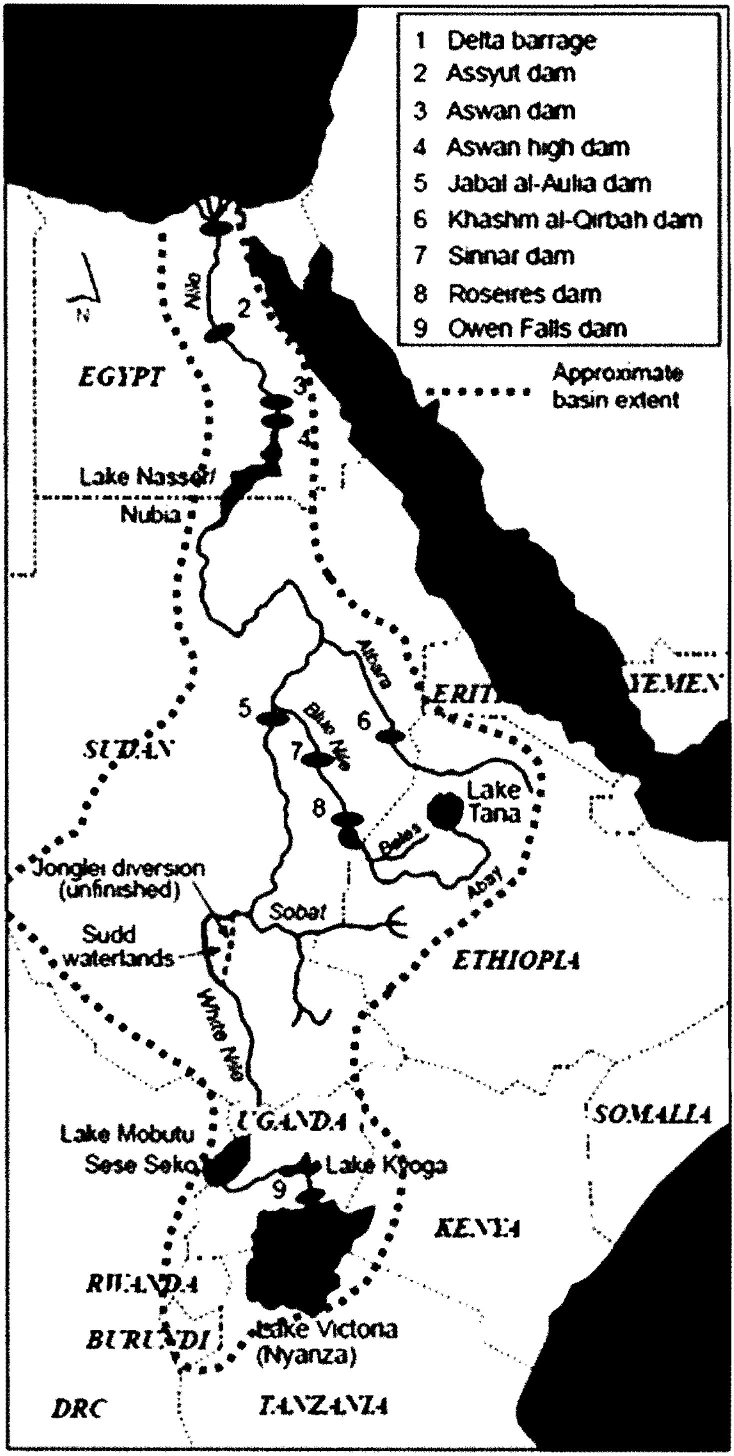

Figure 2.2 Placement of early dams on the Nile. (The map is not to scale.)

Sudan built two dams, which led to the development of the 1929 treaty: the Sennar in 1926 was built primarily to irrigate cotton, while the Jabal Awliya was built in 1936 for both power and irrigation. Later, the Roseires Dam was begun in 1950, and Egypt protested, but reached an agreement with Sudan in the 1959 treaty. Roseires Dam will be raised to add an additional 420,000 ha of irrigated land. The Khashm Al Gerba on the Atbara River was built in 1964 to irrigate the Al-Gerba agricultural scheme and generate 70 MW of power. Recent funding, mostly from China, has helped develop several other huge projects, including the US$1.2 billion Merowe Dam, which displaced 50,000 people and destroyed a number of archaeological sites. The Merowe Dam at the fourth Nile cataract, not up to capacity yet, currently generates 5.5 TWh per year. Controversy is growing on the proposed Dal and Kajbar dams. These two dams above Merowe will transform the stretch of fertile land north of Khartoum into a string of five reservoirs filling in the last remaining Nile cataracts. The Kajbar, located at the third cataract on the Nile River, will cover the heartland of the Nubians, and the Dal at the second cataract will cover what remains of Nubian lands both present and ancient.

The signing of an agreement for the largest construction project any Chinese company has taken on in Sudan is for the Upper Atbara and Setit dam project consisting of two dams, the Rumela Dam on the upper Atbara River and Burdana Dam on the Setit River, located south of the Khashm El-Qurba Dam. The project benefits include an aim to increase irrigated area and agricultural production in New Halfa area currently irrigated by the Khashm El Qurba Dam, regulate flow and reduce flooding, and support development in eastern Sudan.

South Sudan, now after a successful referendum to secede from North Sudan, will consider several hydropower projects in order to modernize southern Sudan. The Nimule Dam, on the border with Uganda, proposed in the 1970s is being considered again as South Sudan needs the Juba to Nimule stretch of the Nile for further power generation. Three large dams have been proposed for this part of the Nile (Mugrat, Dugash and Shereik dams, with projected power generation of 1140 MW) and three additional smaller run-of-the-river projects would also be considered (FAO, 2009). South Sudan might also consider reviewing the Jonglei Canal, but this is a highly political issue and a hypersensitive area in southern Sudan, such that a restart of the canal will need careful consideration (Moszynski, 2011).

Ethiopia has the capacity to become the basin's main power broker as it has huge hydropower potential in the volume of water with a steeply sloping landscape. The estimated potential from the Blue Nile (Abay) alone is about 13,000 MW. Ethiopia has at least six new dams proposed and four under construction. Ethiopia's first big dam, the Finchaa Dam, was completed in 1973 on the Finchaa River that feeds into the Blue Nile. According to Tefera and Sterk (2006), land use changes from the dam have increased soil erosion from expansion of agricultural area, displaced people and reduced grazing areas, swamps and forests.

The Tekeze Dam on the Tekeze River was completed and began operating in 2009. Located at the border with Eritrea, Tekeze was an expensive headache for the Chinese construction company that engineered and built it. Trouble with landslides destabilized the dam and delayed construction. Now the tallest arched dam in Africa (188 m), it cost the Ethiopian government US$350 million. The benefits are the ability to provide water year-round for the downstream areas, besides the generation capacity of 300 MW. The concerns are the construction cost, the sedimentation issues and loss of ecosystems.

On the Abay River, downstream of Lake Tana, the Tis-Abay I hydroelectric project began to transmit power in 1964; later, the CharaChara weir in 1997 was built to boost power supplies and in 2001 another weir, Tis-Abay II was commissioned to boost power supplies by another 20 per cent. Awulachew *et al.* (2009) analysed the possible effects of development on the water resources of Lake Tana and found that water levels would be affected. Later, McCartney *et al.*

(2010) reported that the natural environment around Lake Tana has been affected by the variability in lake levels caused by the weirs. The Tana Beles Dam will transfer water via a tunnel to the Beles catchment for hydropower and irrigation.

In April 2011, the third and newest large dam in Ethiopia, the Grand Millennium Dam, was started. Placed about 40 km from the Sudan border the dam is expected to benefit both Egypt and Sudan. The new dam, estimated to generate 5250 MW, will be completed in about 2017 (Verhoeven, 2011). Funded by the Ethiopian government, it is hoped that future power sales to its neighbours will cover the construction cost, besides helping to boost its own domestic energy supply and access.

Nalubaale Dam, previously Owen Falls at Jinjawas, the first large dam constructed in Uganda, was completed in 1954. Downstream, a new dam is under construction at Bujagali Falls. Delayed four years by many setbacks, the dam was finally started in 2010. It is projected to double power production for Uganda. When Bujagali is finished the Isimba Dam will be built further downstream at Karuma falls. Two smaller run-of-the-river dams, North Ayago, and South Ayago together will boost power by at least 500 MW. Uganda still needs more hydropower and plans to build a total of 14 hydropower dams in the future (Onyalla, 2007). Concerns about environmental issues and implementation of mitigation measures are essential elements that are needed, but often lacking in the planning of many dam projects.

Also in the power development scheme are Burundi, DRC and Rwanda; they have more rainfall and are desperate for power, but lack financial resources. The Kagera River, important to the water balance of Lake Victoria, originates in Burundi and defines borders with Rwanda, Tanzania and Uganda. Most of the Kagera flows through Rwanda. Burundi's interest in the Nile Basin is centred on the Kagera River, where development of hydropower generation is sought. Burundi, Rwanda and Tanzania are jointly constructing the multi-purpose Rusumo Dam and a power plant at Rusumo Falls where the Kagera River forms the boundary between Rwanda and Tanzania, which are on target to transmit power to Gitega in Burundi, Kigali to Kabarondo in Rwanda, and Biharamuro in Tanzania. The details of existing and planned major dams and barrages in the Nile Basin are summarized in Table 2.1. The table is compiled on the basis of multiple sources, as listed below the table.

Development goals of most Nile Basin countries are to reduce poverty, increase agricultural production and provide power for industrial growth. This is where the NBI's Shared Vision Program is set to help joint electrification projects across countries and by regions where ENSAP and NELSAP form joint investments for power transmission between countries. Region-wide transboundary electric trading has yet to be completed due to complications created in multi-country agreements.

Future Nile

What is the future of the Nile? Over the past 10 years the topic of Nile water conflict has appeared in countless articles and news briefs. The number of articles asking this question has increased with the signing of the 2010 Cooperative Framework and with a referendum in southern Sudan in January 2011, leading to a New Nile Basin country, South Sudan, in July 2011. Climate change is also looming in both current and future water developments on the Nile River (Hulme *et al.*, 2001). Pressure on water resources remains the key factor in the political and economic development of the Nile Basin countries, especially with population growth predicted to reach 600 million by 2030.

'Climate change will hit Africa worst', according to Waako *et al.* (2009), who states that climate change is now becoming a key driver in considerations over food and energy security

Table 2.1 Major dams and barrages finished, unfinished and planned in the Nile Basin

Country	*Name of dam*	*River*	*Year completed (or to be started)*	*Power (MW)*	*Storage* (m^3)	*Contractor*
1900s to 1970 post-independence						
Egypt	Assiut barrage	Main Nile	1902	Irrigation		
Egypt	Esna barrage	Main Nile	1908	Irrigation		
Egypt	Nag-Hamady barrage	Main Nile	1930	Irrigation		
Egypt	Old Aswan Dam	Main Nile	1933		450,000	
Egypt	High Aswan Dam	Main Nile	1970	2100	1,110,000	
Ethiopia	Tis-Abay	Lake Tana	1953	12		
Sudan	Sennar	Blue Nile	1925	48	0.93	
Sudan	Jebel Aulia	White Nile	1937	18		
Sudan	Khashm El Gibra	Atbara	1964	35	1.3	
Sudan	Roseires	Blue Nile	1966	60	2.386	
Uganda	Owen/Nalubaale	White Nile	1954	180	0.230	
1970 to present						
Ethiopia	Tekeze 5	Tekeze	2009–2010	300	9.2	
Sudan	Merowe	Main Nile	2009–2010	350	12	
Ethiopia	Finchaa	Finchaa	1971/2013	134	1050	
Ethiopia	CharaChara	Blue Nile	2000	84	9126	
Ethiopia	Koga	Blue Nile	2008	Irrigation	80	
Ethiopia	Tana Beles	Blue Nile	2011	460		
Kenya	Sondu Miriu	Victoria	2007	60	1.1	Japan
Uganda	Kiira/extension	White Nile	1993–2000	200		
Under construction (date gives completion date)						
Sudan	Roseires heightening	Blue Nile	2013			Multi-national
Sudan	Burdana	Setit/Atbara		135		China/Kuwait
Sudan	Rumela	Atbara		135		China/Kuwait
Sudan	Shiraik	Main Nile		300		
Ethiopia	FAN	Finchaa	2011			China/Italy
Ethiopia	Tekeze II	Tekeze	2020			
Ethiopia	Megech	Abay		Irrigation		Multi-national
Ethiopia	Ribb	Abay	2011			
Ethiopia	Grand Millennium	Blue Nile	2017	5250		China/Italy
Rwanda	Nyabarongo	Nyabarongo	2011	27.5		Australia/India
Uganda	Bujagali	White Nile	2011	250		Italy

Table 2.1 Continued

Country	*Name of dam*	*River*	*Year completed (or to be started)*	*Power (MW)*	*Storage (m^3)*	*Contractor*
Dams proposed (date gives potential start date)						
DRC	Semliki	Semliki				
Ethiopia	Jema	Jema				
Ethiopia	Karadobi	Blue Nile	2023	1600		ENSAP
Ethiopia	Border	Blue Nile	2026	1400		ENSAP
Ethiopia	Mabil	Blue Nile	2021			
Ethiopia	Beko Abo	Blue Nile		2000		ENSAP
Ethiopia	Mendaya	Blue Nile	2030	1700		ENSAP
Ethiopia	Chemoda/Yeda five dams proposed	Chemoga/ Yeda rivers	2015	278		China
Ethiopia	Baro I	Sobat				
Ethiopia	Baro II	Sobat				
Sudan	Nimule	Nile				
Sudan	Dal-1	Nile		400		
Sudan	Kajbar	Nile		300		
South Sudan	Bedden	Bahr el Jebel				Italy/NBI
South Sudan	Shukoli	Bahr el Jebel				Italy/NBI
South Sudan	Lakki	Bahr el Jebel				Italy/NBI
South Sudan	Fula	Bahr el Jebel				Italy/NBI
Uganda	Isimba	White Nile	2015	87		
Uganda	Kalagala	White Nile	2011	300		India
Uganda	Karuma	White Nile	2017	200		
Uganda	Murchison	White Nile	600			
Uganda	Ayago North	White Nile	2018	304		
Uganda	Ayago South	White Nile		234		
Uganda	15 small run-of-the river	Kagera				
Rwanda	Kikagate	Kagera	2016	10		
Rwanda	Nyabarongo	Kagera	2012	27		
Rwanda/ Tanzania/ Burundi	Rusumo I & II	Kagera	2012	60		NELSAP
Kenya	Goronga	Mara				
Kenya	Machove	Mara				
Kenya	Kilgoris	Mara				
Kenya	EwasoNgiro	Mara	2012	180		UK

Note: ENSAP = Eastern Nile Subsidiary Action Program

Sources: Ofcansky and Berry, 1991; Nicol, 2003; Scudder, 2005; Dams and Agriculture in Africa, 2007; McCartney, 2007; World Bank, 2007; UNEP, 2008; African Dams Briefing, 2010; Dams and Hydropower, 2010; Kizza *et al.*, 2010; Verhoeven, 2011; Sudan Dams Implementation Unit, undated

in the Nile. Models have been developed to prepare for climate change, but the results are inconclusive (Conway and Hulme, 1993, 1996; Strzepek and Yates 1996; Conway 2005; Kim *et al.*, 2008; Beyene *et al.*, 2009; Kizza *et al.*, 2010; Taye *et al.*, 2010). The issues that users of Nile water face are growing. Most upstream countries are going to want more water, but water is limited and the needs are growing. This creates the potential for conflict. Innovative policies and agricultural practices for the riparian countries are needed, before the situation comes to a hostile end. What steps need to be taken?

There is good news: the greatest potential increases in yields are in rain-fed areas, where many of the world's poorest rural people live and where managing water is the key to such increases (Molden and Oweis, 2007). Leaders need to allow for the creation of better water and land management practices in these areas to reduce poverty and increase productivity. Protecting ecosystems is vital to human survival and must be achieved in harmony. There are opportunities – in rain-fed, irrigated, livestock and fisheries systems – for preserving, even restoring, healthy ecosystems.

Upgrading the current irrigation systems and modernizing the technologies used in irrigation will improve production and make a sustainable irrigation sector in several Nile countries struggling to maintain systems that are no longer productive. Integration of livestock, fisheries and high-value crops will help boost farm incomes.

There is a need to plan for the future, using financial assistance to develop technical training in all countries, work on regional climate models for short- and long-term conditions, and develop methods for hydrometeorological forecasting and modelling of environmental conditions. Climate change will be a main factor in the Nile Basin water security in terms of filling dams and irrigation systems, and creating treaties. Extremes in longer droughts and heavier rains with floods are predicted over the vast areas of the Nile Basin; to cope with these extremes, UNEP and NBI joined forces in 2010 to create a project to prepare for climate change.

It is clear that more cooperation has the potential to generate more benefits equitably from Nile waters. However, the road to cooperation is not easy. But missing that road opens the door to unilateral decision-making, leading to more stress between communities and countries, possibly with disastrous impacts.

Conclusion

Yes, there are challenges, but there are solutions that can help: dialogue, trust and sharing benefits of the Nile water will help solve many of the conflicts between the Nile Basin countries. Cooperation is the key. While the role of the NBI has not yet ended, a comprehensive conclusion is more important now than ever, with water scarcity, increased development and climate change. While there have been important steps for cooperation, much more needs to be done urgently.

For future success in dealing with larger issues of poverty, food insecurity and climate change it will be necessary to conduct successful research with multinational teams working together effectively across borders in the Nile Basin. This is also important to avoid duplication of efforts, to ensure results are easily accessible and make all information commonly available to all the Nile Basin countries.

In the chapters that follow, new insights on poverty, water-related risks and vulnerability, including mapping of these, are provided for the Nile Basin. There is scope for improvement of crop, livestock and fish production in upstream countries, as will be described. Water productivity in the Nile Basin has a large variation. Use of hydronomic zoning in the Nile Basin has helped to identify various zones such as water source zones, environmentally sensitive zones

and farming zones. Finally, through an all-inclusive sustainable and comprehensive agreement, with support from the Nile Commission and the NBI, contributions can be made to agriculture and socio-economic development in the Nile Basin. The past has made the Nile what it is today; it is up to the future to make the Nile provide for all who depend on it.

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