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Wetlands of the Nile Basin

Distribution, functions and contribution to livelihoods

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Key messages

- Wetlands occur extensively across the Nile Basin and support the livelihoods of millions of people. Despite their importance, there are big gaps in the knowledge about the current status of these ecosystems, and how populations in the Nile use them. A better understanding is needed on the ecosystem services provided by the different types of wetlands in the Nile, and how these contribute to local livelihoods.
- While many of the Nile's wetlands are inextricably linked to agricultural production systems the basis for making decisions on the extent to which, and how, wetlands can be sustainably used for agriculture is weak.
- Due to these information gaps, the future contribution of wetlands to agriculture is poorly understood, and wetlands are often overlooked in the Nile Basin discourse on water and agriculture. While there is great potential for the further development of agriculture and fisheries, in particular in the wetlands of Sudan and Ethiopia, at the same time many wetlands in the basin are threatened by poor management practices and rising populations.
- In order to ensure that the future use of wetlands for agriculture will result in net benefits a much more strategic approach to wetland utilization is required; wetland management needs to be incorporated into basin management and, in addition, governance of wetlands should include a means of involving stakeholders from impacted or potentially impacted regions.

Introduction

The Nile is one of the longest rivers in the world, flowing through 10 countries, five of which are among the poorest in the world, with very low levels of socio-economic development (Awulachew *et al.*, 2010). Despite a wide range of productive ecosystems located within the basin, the Nile's land and water resources are not well utilized or managed and are degrading rapidly. While water development interventions and agricultural activities should be undertaken with caution within wetlands, to ensure the maintenance of ecosystem services, they offer a vast livelihood resource and development potential for agriculture and fisheries.

Wetlands and lakes cover approximately 10 per cent of the Nile Basin and play an important role in the hydrology of the Nile River system. Lakes and wetland storage are of particular importance in the White Nile Basin, where spill from the river and its tributaries into wetlands and subsequent evaporation are major components of the catchment water budget (Sutcliffe and Parks, 1999). The area covered is smaller, but wetlands are also important in the Blue Nile. Throughout the Nile Basin, patterns of flow and water chemistry are significantly modified by the complex movement of water within wetlands, which in turn affects the many ecosystem services upon which many millions of people living in the basin depend for their livelihoods.

This chapter provides an overview of the major wetlands in the Nile Basin, their important contribution to livelihoods, and the potential threats to the ecosystem services and functions they provide. Wetlands across the basin support agriculture (including livestock) and fisheries activities, and provide a critical dry-season resource, in particular in areas of low and erratic rainfall (i.e. much of the basin). Their importance to livelihoods will increase under future climate change scenarios and expanding populations, and with continuing pressure to improve food security in Nile Basin countries. Although many of the wetlands in the basin are not currently exploited to their full potential in terms of agriculture and fisheries activities, they are under threat. Better management of these ecosystems is vital, along with integration into water resources and basin management. If wetlands are not used sustainably, the functions that support agriculture as well as other food-security and ecosystem services, including water-related services, are undermined. Trade-offs between the various uses and users need to be better evaluated in order to guide management responses, and there is a pressing need for more systematic planning that takes into account trade-offs in the multiple services that wetlands provide.

Overview

The Nile River supports a range of wetland ecosystems distributed across the entire length of the basin (Figure 11.1), although there is a higher concentration in the upstream regions of both the Blue and White Nile. Defined by the Ramsar Convention (Article 1.1) as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres', wetlands are estimated to cover 18.3 million ha (i.e. about 5%) of the basin. These ecosystems are found at the source of the Blue Nile in Ethiopia (Lake Tana and associated floodplains) and along the tributaries of the Blue Nile and Atbara in Ethiopia (e.g. Finchaa, Didessa, Tekeze) and in Sudan (e.g. the Dinder). There are numerous wetlands at the source of the White Nile in the Equatorial Lakes region, in particular around Lakes Victoria, Albert and Kyoga. Further downstream, the Bahr el Jebel (the upper reach of the White Nile) enters the Sudan plains forming the vast Sudd wetland. Large wetlands are also found to the west of the Sudd, fed by the Bahr el Ghazal before it joins the Bahr el Jebel outflow from the Sudd at Lake No. Located on tributaries of the While Nile are the Baro-Akobo wetlands in Ethiopia and the Machar Marshes in Sudan. Upstream of Khartoum where the Blue and White Nile rivers merge, the Nile flows through the desert with only small fringing wetlands observed until it forms the Nile Delta at the Mediterranean Sea.

Within the basin 14 sites have been nominated by the individual countries as Ramsar Wetland Sites of International Importance (Table 11.1). These include one site in the Democratic Republic of Congo (DRC), 11 in Uganda and two in Sudan, covering a total area of 7.9 million ha. The only basin countries which are currently not signatories to the Ramsar convention are Ethiopia and Eritrea.

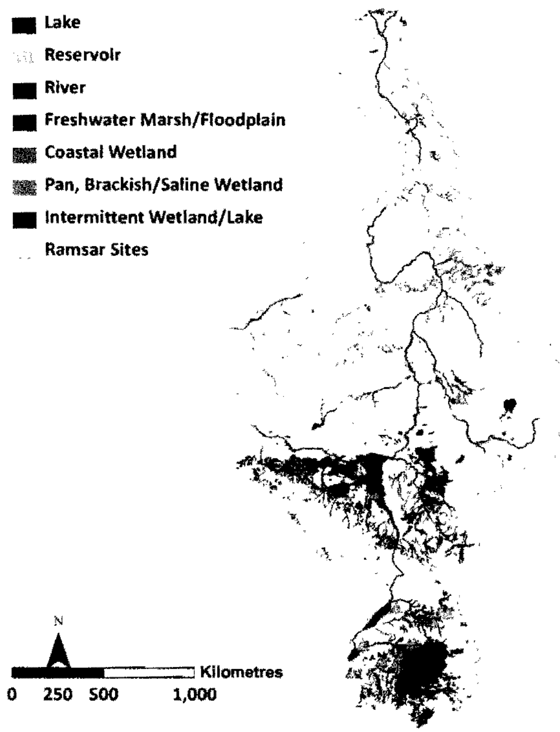

Figure 11.1 Spatial distribution and areal extent of wetlands within the Nile Basin

Source: Data are derived from the Global Lakes and Wetlands Database (Lehner and Döll, 2004) and country-based Africover data sets (FAO, 2002)

Table 11.1 Ramsar Wetland Sites of International Importance located within the Nile Basin

Country	*Site*	*Wetland area (ha)*	*Dominant type*
DRC	Virunga National Park	800,000	Permanent freshwater lakes
Uganda	Lake George	15,000	Permanent freshwater lakes
	Lake Nabugabo	3600	Permanent freshwater lakes
	Lake Bisina	54,229	Permanent freshwater lakes
	Lake Mburo-Navikali	26,834	Permanent freshwater lakes
	Lake Nakuwa	91,150	Permanent freshwater marshes or pools
	Lake Opeta	68,912	Permanent freshwater marshes or pools
	Lutembe Bay	98	Permanent freshwater marshes or pools
	Mabamba Bay	2424	Permanent freshwater marshes or pools
	Nabajjuzi	1753	Permanent freshwater marshes or pools
	Murchison Falls – Albert Delta	17,293	Permanent freshwater marshes or pools
	Sango Bay – Musambwa Island – Kagera	55,110	Seasonal/intermittent freshwater lakes
Sudan	Dinder National Park	1,084,600	Seasonal/intermittent freshwater lakes/ rivers
	Sudd	5,700,000	Permanent/seasonal rivers

Wetland ecosystem services

Ecosystem services are defined by the Millennium Ecosystem Assessment (MEA, 2005) as 'the benefits people obtain from ecosystems'. Different wetlands across the Nile Basin perform different functions thereby providing different ecosystem services, depending on the interactions between their physical, biological and chemical components, as well as their surrounding catchments. Ecosystem services are typically categorized into four groups; provisioning, regulating, supporting and aesthetics (Figure 11.2). The physical benefits which people derive from wetlands include provisioning services such as domestic water supply, fisheries, livestock grazing, cultivation, grasses for thatching, and wild plants for food, crafts and medicinal use. Wetlands in the Nile Basin play an important role in sustaining the livelihoods of many millions of people through the provision of numerous ecosystem services, including food. In many places these ecosystems are closely linked to cropping and livestock management. In arid and semi-arid regions with seasonal rainfall patterns the capacity of wetlands to retain moisture for long periods, sometimes throughout the year and even during droughts, means that they are of particular importance for small-scale agriculture, both cultivation and grazing. Such wetlands often provide the only year-round source of water for domestic use.

Other wetland ecosystem services are often not explicitly recognized by communities, but include a wide range of regulating services such as flood attenuation, maintenance of dry-season river flows, groundwater recharge, water purification, climate regulation and erosion control, as well as a range of supporting services such as nutrient cycling and soil formation. In addition, people also gain non-physical benefits from the cultural services, including spiritual enrichment, cognitive development and aesthetic experience. At many sites, the different types of service may be closely linked.

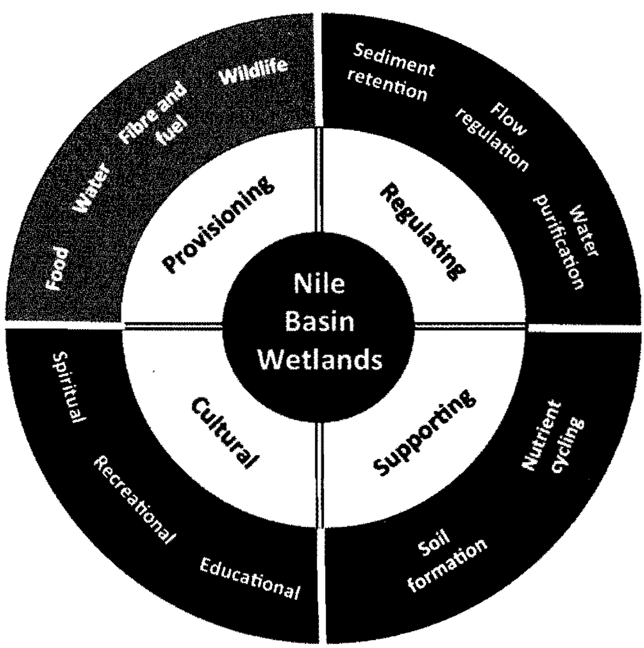

Figure 11.2 Wetland ecosystem services

Contributions to water resources

Due to their role in the provisioning of water, regulating flows and improving water quality, wetlands are increasingly perceived as an important component of water infrastructure (Emerton and Bos, 2004). The flow regulation functions of the various Nile wetlands contribute to the hydrology of the whole basin, although the magnitude of the contribution of an individual wetland depends on its type, location within the catchment and the presence/absence of upstream water resources infrastructure (Table 11.2). Because of their dependence on water and their importance in the hydrological cycle, it is essential that wetlands are considered as a key component in strategies for Integrated Water Resources Management (IWRM).

Table 11.2 Hydrological functions of major wetlands in the Nile Basin

Wetlands	*Hydrological functions*
Wetlands of Uganda	Most of the individual wetlands link to other wetlands through a complex network of permanent and seasonal streams, rivers, and lakes, making them an essential part of the entire drainage system of the country (UN-WWAP and DWD, 2005)
Headwater wetlands of the Baro Akobo	Regulate flow in the Baro Akobo River while believed to play an important role in maintaining downstream dry-season river flows
Lake Albert	Critical link between the White Nile and its headwaters; without the flow regulation of this lake the White Nile would be reduced to a seasonal stream and could play no significant role in maintaining the base flow of the main Nile (Talbot and Williams, 2009)
Sudd, Machar Marshes and wetlands of the Bahr Ghazal	Significantly attenuate flows of the White Nile and its tributaries reducing flood peaks and supporting dry-season river flows, thereby minimizing the seasonal variation in the flow of the White Nile (Sutcliffe and Widgery, 1997; Sutcliffe and Parks, 1999)
Nile Delta	Limits saline intrusion from the Mediterranean Sea, thereby protecting coastal freshwater sources (Baha El Din, 1999)

Wetlands can be very effective at improving water quality and, consequently, can be very important in the treatment of polluted water. This function of wetlands is achieved through processes of sedimentation, filtration, physical and chemical immobilization, microbial interactions and uptake by vegetation (Kadlec and Knight, 1996). In Uganda, sewage from 40 per cent of the residents of the city of Kampala (numbering approximately 500,000) is discharged into the 5.3 km^2 Nakivubo wetland. During the passage of the effluent through the wetland, the papyrus vegetation absorbs nutrients and the concentration of pollutants is reduced before the water enters Lake Victoria, the principal water source for the city (Kansiime and Nalubega, 1999). The water purification services of this wetland are estimated to be worth about US$1 million per year (Emerton, 2005).

Case studies

The Sudd wetland

While wetlands are found in all the Nile Basin countries, the largest and most important to the hydraulics of the downstream river is the Sudd in South Sudan. Derived from an Arabic word meaning obstacle or blockage of river channels, the Sudd is located between 6°0'–9°8' N and 30°10'–31°8' E (Figure 11.3). Its width varies from 10 to 40 km and its length is approximately 650 km. It is the largest freshwater wetland in the Nile Basin, one of the largest floodplains in Africa and one of the largest tropical wetlands in the world. Covering the area between the town of Mongalla in the south and Malakal in the north, the area of permanent swamps stretches over approximately 30,000 km^2 with the lateral extent of seasonal flooding varying considerably depending on the inflow conditions and season. In periods of high flood and rainfall such as in 1917–1918, 1932–1933, 1961–1964 and 1988–1989, the floodplain remained flooded well into the dry season, while during periods of low flood and rainfall such as in 1921, 1923 and 1984, the floodplain shrinks to the extent that even the permanent swamps dry up.

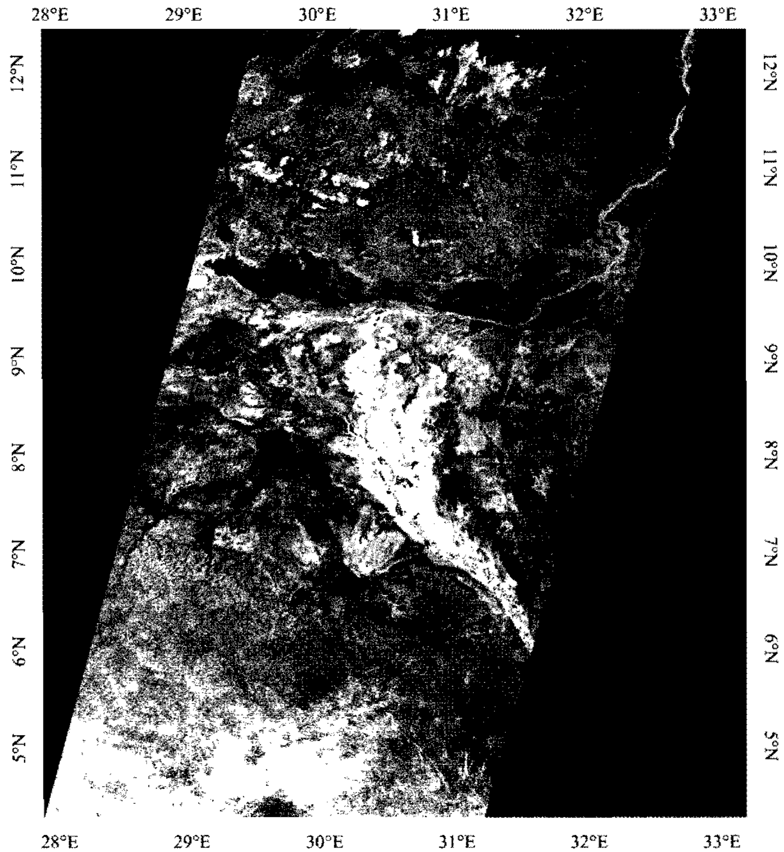

Figure 11.3 The Sudd, South Sudan, June–December 2007

Source: ALOS PALSAR data © JAXA/METI

The Comprehensive Peace Agreement, signed in 2005, ended 22 years of civil war in Sudan, and subsequently (in 2006) 57,000 km^2 of the floodplains of the Sudd were designated as a Ramsar Wetland Site of International Importance. Prior to this designation, three protected areas already existed within the Sudd region. These cover a total area of over 10,000 km^2 and include Zeraf Game Reserve (9,700 km^2, established in 1939), Shambe National Park (620km^2, established in 1985) and Fanyikang Game Reserve (480km^2, established in 1939).

The Sudd is part of the Bahr el Jebel system (the upper reach of the White Nile in Sudan), which originates in the African Lakes Plateau. Seasonal inundation drives the hydrologic, geomorphological and ecological processes and the annual flood pulse is essential to the functioning of the wetland. Flow in the Bahr el Jebel controls not only the hydrology but also many of the other biophysical characteristics of the Sudd (Sutcliffe, 2009). The inundated area of the Sudd varies both within and between years, as inflow and rainfall vary. Annually, the maximum extent of flooding occurs after the rainy season (i.e. between October and December). The rise of Lake Victoria is estimated to have resulted in a trebling of the area of permanent swamps after 1964, a smaller increase in the area of seasonal flooding and a decrease in the inter-annual variability of the flooded area (Sutcliffe and Parks, 1999).

The Sudd wetland comprises a complex maze of various ecosystems. Habitats within the region grade from open water and submerged vegetation to floating fringe vegetation, seasonally flooded grasslands, rain-fed grasslands and, finally, floodplain woodlands (Hickley and Bailey, 1987). The core area of the permanent swamps is dominated by *Cyperus papyrus*, with communities of *Phragmites communis* and *Vossia cuspidata*, bordered by stands of *Typha domingensis*. *Eichornia crassipes* (water hyacinth) found along the open channels. Surrounding the permanent swamps are vast floodplains which consist of seasonally river-flooded grasslands (referred to locally as '*toic*'). These are estimated to cover an area of approximately 16,000 km^2 (WWF, 2010) and are dominated by species of *Oryza longistaminata* and *Echinocloa pyramidalis*. An estimated 20,000 km^2 of rain-fed *Hyparrhenia rufa* grasslands surround the river floodplain (Robertson, 2001). Beyond these are the floodplain woodlands which are dominated by *Acacia seyal*, and *Balanites aegypticaca*. This diverse range of habitats supports a rich array of aquatic and terrestrial fauna including over 400 bird and 100 mammal species (Rzóska, 1974).

The Sudd and the surrounding areas are used extensively by the Dinka, Nuer and Shilluk tribes. The Sudd provides a source of water and essential dry-season grazing land for livestock, the backbone of the Nilotes' economy. The Nilotic pastoralists use a transhumance system to optimize the seasonal flooding and drying cycle, moving with their large herds of cattle in response to the annual regime of the Bahr el Jebel and rainfall. Three of the Sudd vegetation communities are used extensively for livestock grazing (Denny, 1991): river-flooded grassland, the most productive for year-round grazing because the dead grass has a high protein content; seasonally flooded grassland, which includes rain-flooded grasslands, seasonally inundated grasslands, and rain-fed wetlands on seasonally waterlogged clay soil, all three of which are heavily used by livestock; and floodplain scrub forest, at higher elevations on well-drained soils around the floodplains. Before the onset of the civil war the number of livestock using the floodplains of the wetland during the dry season was estimated to be 700,000 (Howell and Lock, 1988). There are no recent counts of livestock populations, but many Internally Displaced Persons are returning with their cattle, and head of livestock are likely to have increased. Recent estimates suggest the livestock population is 1 million head (BirdLife International, 2008), resulting in one of the highest cattle to human ratios in Africa (Okeny, 2007).

While livestock have historically been central to Sudan's economy, their contribution declined from 20 per cent of the GDP in 1999 to 3.2 per cent in 2005 (Fahey, 2007). In addition to the increase in oil exports, the decreasing contribution of livestock and related products is attributed to supply constraints (inadequate capacity at the port, deterioration in the road infrastructure), conflict in livestock-rich areas (in particular the Sudd region), and higher domestic demand (IMF, 2006). The Sudd region has a high potential for livestock, which could markedly contribute to the new economy of South Sudan. Increasing Sudd livestock productivity would also greatly improve the livelihoods of Sudd residents. Livestock production in South Sudan currently faces major challenges including limited access to water during the dry season, high levels of poverty and disease, and a rapidly growing population. Livestock is the most important source of income in the rural areas; however, it is also a potential contributor to water scarcity during the dry season. Although this topic requires further research, initial recommendations for improvements in the Sudd include: water storage with small ponds and larger reservoirs, access to, and development of, bore holes, promotion of productive range ecosystems with efficient livestock management, and establishment of organized livestock markets. In addition, agricultural and livestock training centres would educate herders, develop ranching systems, assist in a comprehensive livestock census within the context of the Sudd area to help in planning and management, provide veterinary services along with human health care services and build an awareness campaign for peace-building activities.

Fishing is the second most important occupation of the inhabitants of the wetlands, in particular for the Shilluk and Nuer tribes, and is typically conducted seasonally alternately with crop production and livestock-rearing. The Sudd is one of the only water bodies of the Nile which is currently not overfished, and the potential yield (based on a surface area of 30,000–40,000 km^2) has been estimated at 75,000 tonnes per year (Witte *et al.*, 2009). However, no direct stock assessment studies have ever been conducted for the Sudd fisheries. Many fish species migrate from the surrounding rivers to the nutrient-rich floodplains to feed and breed during the seasonal floods (Welcomme, 1979). While South Sudan has vast aquatic and fisheries resources with over 130 fish species reported, the full potential of these has yet to be exploited. This is mainly due to the lack of processing and storage facilities and inadequate transportation infrastructure both of which have limited the development of commercial fisheries.

Machar Marshes

A large expanse of wetlands comprising lakes and floodplains is found in the eastern part of Sudan and western Ethiopia, east of the White Nile and north of the Sobat rivers. Located between 8°27'–9°58' N and 32°11'–34°9' E, the wetland system extends at least 200 km from north to south and 180 km from east to west (Hughes and Hughes, 1992). The wetlands are fed by a combination of local precipitation, the torrents originating in the Ethiopian Highlands, and spillover from the Baro, the Akobo and the Sobat. Both the Baro and Akobo rivers spill during periods of high flows into the adjoining wetlands while the Baro spills north across the Ethiopia-Sudan border towards the Machar Marshes (Sutcliffe and Parks, 1999). Hughes and Hughes (1992) estimate the total area of the wetlands at around 9000 km^2, 5000 of which are located in Sudan and 4000 in Ethiopia, while the wetland along with the area of grassland which floods annually has been estimated to be between 6000 and 20,000 km^2 (JIT, 1954).

The Machar Marshes are one of the least studied wetland systems in the Nile Basin, and there is little information available in the literature describing the vegetation characteristics, the seasonal patterns of inundation, or livelihood activities within the wetland. It is noted by Sutcliffe and Parks (1999) that the hydrological regime of the Sobat is complicated by the influence of the wetlands, and the relative remoteness of these has meant that hydrological measurements and study have been less advanced than in the other tributaries. Hughes and Hughes (1992) describe the Marshes as extensive grassy floodplains and permanent swamps dominated either by papyrus along the watercourses or by *Phragmites* and *Typha* away from them. It is suggested that the area experiences a high variability in the timing and intensity of flooding, and that this may have an impact on the establishment of permanent wetlands dominated by vegetation such as papyrus sedge, *Phragmites* and *Typha* (Hassan *et al.*, 2009).

The floodplains are used for livestock grazing in the dry season, while hunting and fishing take place within the wetland. However, Hughes and Hughes (1992) note that the Marshes are little utilized due to the very low population density in the region, and more up-to-date information is not available. In Ethiopia, the Baro and Akobo wetlands provide direct benefits to more than half the population of the region through the provision of water, fisheries, construction materials and medicinal plants as well providing areas of grazing and cultivation.

The Nile Delta

The Nile Delta in northern Egypt is an extensive wetland system, comprising lakes, freshwater and saline wetlands and intertidal areas. Covering an area of approximately 22,000 km^2 encompassing 240km of the coastline (west to east) and 175km in length (north to south), it is one of the largest river deltas in the world (Hughes and Hughes, 1992). Formed as the Nile enters the Mediterranean Sea, the completion of the first Aswan Dam (between 1912 and 1934) dampened the annual flood pulse in the delta. The completion of the second, the Aswan High Dam (AHD), stopped flooding completely and most of the former seasonally or permanently flooded habitats have subsequently been converted to agriculture. Originally intended to produce clean energy and to conserve and protect agriculture (increasing cultivable land by 30%) by controlling the annual Nile flood, it had a dramatic negative effect on the sediment flux to the delta (Hamza, 2009). The delta is now composed of two branches, Rosetta and Damietta and has traditionally been one of the most important agricultural areas of Egypt (Dumont, 2009).

The delta is a very rich agricultural region, and before construction of the AHD recession farming had been practised on the floodplain for over 5000 years. Since the completion of the AHD the area is farmed year-round, causing the loss of much of the wetland habitat of the delta and lower Nile River floodplain. In addition, as the delta no longer receives an annual supply of nutrients and sediments from upstream due to the dam, the floodplain soils have become poorer and large amounts of fertilizers are now used. Although once known for the large papyrus (*Cyperus papyrus*) wetlands, due to the reduction in flooding these have largely disappeared and the remaining wetland consists of lakes and lagoons along the seaward side of the delta. Intensified by the construction of the AHD and other dams and barrages along the upper and lower Nile, and the extensive regulation of the Nile's waters, the delta is in an acute stage of subsidence (Stanley and Warne, 1994). The outer margins are eroding and salinity levels of some of the coastal lands are rising as a result of sea water infiltration to the groundwater (Hughes and Hughes, 1992; Baha El Din, 1999).

Fisheries and agriculture in the Nile Delta are well developed. Covering an area of approximately 22,000 km^2, the delta accounts for two-thirds of Egypt's agriculture. Although the delta comprises only 2.8 per cent of the country's area, it is home to 63 per cent of Egypt's population of 80 million, and is the most populated, cultivated and industrialized part of the country (Hamza, 2009). Due to the reduction of siltation as a result of the AHD farmers now have to use approximately 106 tonnes of artificial fertilizer as a substitute for the nutrients which no longer reach the floodplain, and salinity and waterlogging problems have developed due to over-irrigation (El-Shabrawy, 2009).

While fisheries have long been an important source of food and income to the inhabitants of the Nile Delta, the AHD has also had an impact on fish populations. Prior to its construction, the migrations of various fish species were dependent on the annual flood water. Following the construction of the AHD, the fish catch in the Mediterranean declined from 22,618 tonnes in 1968 to 10,300 tonnes in 1972, recovering to 13,450 tonnes in the 1980s (Biswas, 1992). Sardines, for example, used to breed in the Nile estuary but have now almost disappeared, and marine fish that used to seasonally migrate into the delta lakes have been virtually eliminated. Their place has, however, been taken by freshwater species (El-Shabrawy, 2009). In addition, with Lake Nasser the AHD created a completely new source of fish, which was producing 32,000 tonnes by 1982, thereby compensating for the initial loss of the Mediterranean catch (Biswas, 1992). More recently, exploitation of the delta fisheries has occurred at a level that is not sustainable (Dumont and El-Shabrawy, 2008) and, as a result, recent emphasis has focused on farmed fisheries, and aquaculture is currently booming in the delta. The expansion of aquaculture has resulted in the significant increase of total fisheries production in Egypt. The relative importance of Egyptian aquaculture to total fisheries production has increased from 16 to 56 per cent of total fisheries production between 1997 and 2007.

Other Nile wetlands

While the previous sections have focused on three of the large wetlands of the Nile, many other, equally significant, wetlands are also found across the basin. Located in the Ethiopian Highlands, Lake Tana is the largest freshwater lake in Ethiopia and is the source of the Blue Nile. The lake, covering an area of 3,156 km^2, is shallow, with an average depth of 8 m, and is the third largest lake in the Nile Basin. The lake is bordered by seasonal floodplains such as the Dembea in the north, the Fogera in the east, and the Kunzila in the west. Permanent *Cyperus papyrus* wetlands fringe much of the lake, forming the largest lake-wetland complex in the country. Lake Tana and adjacent wetlands support directly and indirectly the livelihoods of a population of over 500,000, and constitute the country's largest rice production area (Vijverberg *et al.*, 2009). During the rainy season the wetlands are connected with the lake, and act as nurseries for most of the fish populations in the lake, as well as serving as breeding grounds for waterfowl and mammals (Vijverberg *et al.*, 2009).

Wetlands are also located along the tributaries of the Blue Nile, such as the floodplain between the Dinder and Rahad rivers in Sudan, which is composed of a series of wetlands and pools which are part of the drainage systems of the two rivers. Like many wetlands in the basin, the Dinder wetlands on the Blue Nile in Sudan are an important source of water and nutritious grasses to livestock, in particular during the most severe period of the dry season.

Lake Victoria is the source of the White Nile and, with a surface area of approximately 68,800 km^2, is the second largest lake in the world. The White Nile outflow from Lake Victoria controls the levels of Nile base flow into Sudan and Egypt. The water balance of the lake is controlled mainly by precipitation over, and evaporation from, the lake, which vary greatly from year to year according to cloud cover and surface radiation balance (Lehman, 2009). Since 1956, outflow from the lake has been regulated by the Nalubaale Dam constructed for hydroelectric power generation at Owen Falls. Although it once supported species-rich fish communities, the introduction of exotic species and the commercial exploitation of these have drastically changed the biodiversity of the ecosystem. Lake Victoria is the second major commercial fishery in the basin, with the livelihoods of 1.2 million people directly or indirectly dependent on the lake fishery (Matsuishi *et al.*, 2006). In 2003, the estimated annual catch was worth over US$540 million in terms of fish landings, with a further US$240 million earned in fish exports (Balirwa, 2007). There is high population density around the lake, which serves a variety of important socio-economic purposes. It plays a vital role in providing drinking water for the major urban areas and lake shore communities, provides cheap animal protein to the surrounding populations, as well as supplying water to the lake basin, which is the most agriculturally productive and industrialized region in Uganda (Baecher *et al.*, 2000).

Located downstream of Lake Victoria, Lake Kyoga is a shallow lake surrounded by wetlands. During periods of low water, the lake splits into a series of satellite lakes with swamps of *Cyperus Papyrus* forming barriers between them when water levels rise. The lake and surrounding wetlands provide an important supply of water for domestic uses and livestock to the local population. Fishing is the main livelihood activity in the region, and subsistence and small-scale crop production is also undertaken. Between the late 1960s and the early 1980s, until the Victoria Nile perch fishery expanded, Lake Kyoga fish production was higher than that of Lake Victoria, reaching a peak in 1983 with 180,000 tonnes (75% of national production). Lake Kyoga discharges into Lake Albert, where large seasonal wetlands are found. Smaller seasonal wetlands are found along the banks of the Nile from Lake Albert to the border with Sudan. Wetlands are also found on tributaries to the White Nile; in the Baro Akobo catchment in south-western Ethiopia (i.e. the Illubabor region) with approximately 5 per cent of the land area covered by seasonal headwater wetlands. Extensive floodplains are found along the course of the Bahr el Ghazal, a tributary of the White Nile located to the west of the Sudd. The Bahr el Ghazal wetlands are estimated to cover an area of around 9000 km^2, with flora, fauna and livelihood activities similar to those of the Sudd (Hughes and Hughes, 1992). The river has a negligible impact on downstream Nile flow as only 2–3 per cent of the river flow reaches the White Nile as the remainder of the river inflow of the Bahr el Ghazal Basin (12 billion $m^3 yr^{-1}$) is evaporated before reaching the Nile (Sutcliffe and Parks, 1999; Mohamed *et al.*, 2006).

Threats to Nile wetlands

Nile Basin wetlands are vulnerable to a range of factors including water resource infrastructures, conversion to agriculture, increasing populations and overexploitation of resources, invasive species, extraction of minerals and oil, and climate change. Many hydrological interventions already exist or are planned across the Nile Basin in order to increase economic benefits and food security. However, these interventions will not be without negative consequences and both the costs and benefits need to be carefully evaluated. One likely consequence of increased flow regulation is reduced downstream flooding and dampening of the seasonal flood pulse, both of which will have an impact on wetlands. Uganda, Ethiopia and Sudan all have ambitious plans for dams along both the main stem of the White Nile and its tributaries, and the construction of these is already underway in some locations. In addition, it is not yet clear whether construction of the Jonglei canal (Figure 11.1), a major threat to the Sudd, will be resumed, with the aim of reducing evaporative losses from the Sudd and increasing water for irrigation downstream. The pastoral economy of the Sudd is dependent on the annual flooding which depends on relatively steady outflows from Lakes Victoria and Albert and the seasonal flows of the torrents above Mongalla. Any alteration of the natural flow would affect the regime of the Bahr el Jebel and the Sudd and would disrupt the economy of the area (Sutcliffe and Parks, 1999). If completed, the canal is also likely to have a significant impact on Nile hydrology, groundwater recharge, sedimentation and water quality; it is also likely to result in the loss of biodiversity, livestock grazing areas and fish habitats, and to interfere with the seasonal migration patterns of both cattle and wildlife, all of which will have an effect on the livelihoods of the local populations (WWF, 2010).

Dams on the Blue Nile and its tributaries also need careful consideration; under normal conditions, the Baro River only breaks its northern banks and provides water to the Machar Marshes when in peak flow. If water is extracted or stored upstream of this overflow so that the peak flows are reduced to a level that does not permit spillage northwards, the area of seasonally flooded marshes will be significantly reduced with serious effects on livestock and wildlife dependent on that wetland (Baecher *et al.*, 2000). Any dam built for storage and hydropower generation on the upper reaches of the Akobo or Baro rivers should therefore be reviewed for its ability as a regulator and flexible control structure with the goal to alter the rise of the Baro as little as possible, as this is the system that sustains the southern Machar Marshes (Baecher *et al.*, 2000).

Dams and the artificial wetlands that they create have brought some significant benefits to the region. For example, the construction of the AHD has significantly increased the amount of land available for agriculture, lengthened the agricultural year and provided hydroelectricity, thus benefiting many millions of people in Egypt (Biswas, 1992). However, dams almost always also bring about negative impacts, particularly for wetlands and the people who depend on the ecosystem services that wetlands provide. For example, the construction of the AHD has affected both the quantity and quality of discharge, and the limited Nile nutrient-rich sediments and water reaching the delta have negatively affected both the agricultural activities and the functioning of the ecosystems in the coastal area adjacent to the delta (Hamza, 2009).

While many wetlands in the Nile Basin support agriculture, trade-offs associated with the conversion of wetlands for agricultural use need to be carefully evaluated to ensure that the ecosystem services supported are not undermined. With the population of the Nile Basin predicted to grow to 300 million by 2010 and 550 million by 2030, increased pressure and competition for, and overexploitation of, increasingly scarce resources are to be expected. The need for appropriate management of wetland resources to ensure their sustainable use is therefore a matter of urgency. The conversion of wetlands to agriculture in Uganda has occurred extensively, affecting the hydrologic functioning of these wetlands (Baecher *et al.*, 2000). Conversion of wetlands for agricultural use is also a widespread practice in Ethiopia, in particular in the Baro Akobo wetlands (Teferi *et al.*, 2010). Across the country, wetlands are being lost or altered by unregulated overutilization including extraction of water for agricultural intensification, urbanization, dam construction, and pollution (Abunie, 2003). In this region, escalating population and the resultant need for increased food have resulted in increased agriculture in the wetlands and their subsequent degradation. The Nile Basin's most polluted wetlands are those of the Nile Delta, where irrigation drainage water, untreated or partially treated urban wastes and industrial effluents have reduced water quality, destroyed several forms of aquatic life, reduced the productivity of the fisheries and contaminated the fish catch (UNEP, 2006). In Sudan, the Sudd has come under considerable pressure during the past few years. Hunting has been uncontrolled during the civil war and with the signing of the CPA in 2005 the inflow of large numbers of refugees as well as their cattle has put pressure on the natural resources due to competition for grazing land, deforestation and infrastructural development.

In contrast to the Sudd, the degradation of Lake Victoria has been occurring for several decades. The fish community has been transformed from its native state of high species richness to a much simpler, largely introduced, fauna that appear to be unstable under prevailing exploitation regimes; nutrient enrichment and climate warming have contributed to deoxygenation of deep water habitats and promoted the rise of Cyanobacteria and other changes in the lower food web, and the lake now behaves as a light-limited, nutrient-saturated ecosystem that is becoming biologically sensitive to both the radiation balance and the water budget (Lehman, 2009). Overfishing has also had its effect on Nile perch in both Lake Victoria and

Lake Kyoga where the populations have lessened significantly. The aquatic diversity and fisheries of many other wetlands in the basin including the Sudd, Lake Kyoga and the Nile Delta are also vulnerable to invasive species such as the water hyacinth (*Eichhornia crassipes*).

Wetlands often contain rich reserves of oil and other mineral deposits, and those in the Nile Basin are no exception (De Wit, 2008). The Nile Delta area is currently Egypt's main source of hydrocarbons and natural gas, and the chemical industries located in the delta are a major source of hazardous waste (Hamza, 2009). In Sudan, recent discovery and exploitation of oil reserves in the Sudd threatens the diversity of the wildlife, aquatic macrophytes and floodplains, as well as the hydrology of the intricate ecosystem. Several blocks have already been allocated to oil companies and exploration drilling is under way in the permanent swamps. Concerns surrounding the exploration and extraction of oil include disruption of water flow patterns as a result of seismic testing and diking; wetland and floodplain fragmentation due to access roads and oil exploration sites; and contamination due to oil spills and human waste.

Some impacts of climate change are already being observed globally, and the *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC) confirmed that 'warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level' (IPCC, 2007). Other impacts, because of inertia in the climate system and complex feedback mechanisms, will only become apparent in the future. However, the knock-on effects of changes in the climate, stemming largely from changes in rainfall and evaporation, will cause changes in many other natural systems, including wetlands.

Currently, there is considerable uncertainty about the exact impact of climate change in the Nile Basin. Results from global climate models (GCMs) are contradictory; some show increases in rainfall whilst others show decreases. A recent study of 17 GCMs indicated that precipitation changes between −15 and +14 per cent, which, compounded by the high climatic sensitivity of the basin, translated into changes in annual flow of the Blue Nile at the Sudan border of between −60 and +45 per cent (Elshamy *et al.*, 2008). Kim *et al.* (2008) found a generally increasing trend in both precipitation and run-off in the northern part of the Blue Nile Basin. To date, no studies have been conducted into the secondary impacts of climate change arising from changes in temperature and rainfall (e.g. changes in irrigation demand), which are also likely to affect run-off and river flows and hence wetlands.

Rising sea levels, both climate-related and due to other factors, will have an impact on coastal wetlands Eustatic rise alone is estimated to potentially result in the loss of 22 per cent of the world's coastal wetlands by 2080 (Nicholls *et al.*, 1999). Rising sea levels would weaken the Nile Delta's protective sand belt, with serious consequences for essential groundwater, inland freshwater fisheries and the large expanses of intensively cultivated agricultural land (IIED, 2007). Future scenarios based on anticipated conditions of fluvial input, delta subsidence and acceleration of eustatic rise have been used to estimate land loss in the Nile Delta, with worst-case scenarios indicating a habitable land loss of 24 per cent by 2100 (Milliman *et al.*, 1989).

The lack of certainty in trends in rainfall, run-off and sea-level rise will greatly complicate future wetland management. It is likely that in some places in the basin increased rainfall and run-off will cause increases in flow into wetlands and vice versa, and even small rises in sea level will have large impacts on the delta. Further research is needed to improve quantitative understanding of the impacts of climate change on basin hydrology and hence on wetlands.

Conclusions and recommendations

Wetlands of various types occur across the length of the Nile Basin. These ecosystems are a vast livelihood resource, and either have the potential to contribute to, or already contribute in diverse ways to, the livelihoods of millions of people. Levels of wetland resources use vary considerably across the basin; while some ecosystems, such as Lake Victoria may currently be exploited to their full potential, others, such as the Sudd, can be further developed.

Livestock, fisheries and aquaculture are fundamental needs in the daily lives of people along the Nile, but they have been neglected topics in the water discourse. Livestock are essential to many groups in the Nile Basin; they establish the wealth of a family and ability to marry, and indicate the social standing of several groups within the Nile Basin countries. In many places throughout the basin, pastoralists are wholly dependent on wetlands to maintain their cattle and other animals. The Sudd region has a high potential for livestock, which could markedly contribute to the new economy of South Sudan; increasing livestock productivity in the Sudd would also greatly improve the livelihoods of Sudd residents.

Fish is a major source of protein across the basin, and there is scope for improvement in various Nile wetlands. Egypt has the best developed fisheries industry, and in some areas, overexploitation is suspected to occur. Fish landings in the delta lakes, for example, now overshoot the limits of sustainability (Dumont and El-Shabrawy, 2008). Fisheries contribute significantly to the GDP of Egypt and Uganda. In Uganda, fisheries also play a very important role for subsistence as well as for a commercial livelihood. While Lake Victoria is the largest and most important economically, other large lakes, including George, Edward, Albert and Kyoga, and associated wetlands also contribute substantially to the annual national catch. The Sudd and other wetlands contain huge untapped potential for fisheries. Fish farming has begun to play an increasingly important role in Egypt, where over 90 per cent of the basin's aquaculture is currently practised. However, there are opportunities elsewhere for the development of aquaculture.

The contribution of Nile wetlands to the livelihoods of local populations, as well as to the economies of the basin countries, is clear. Despite their importance, there are big gaps in the knowledge about the current status of these ecosystems, and how populations in the Nile use them. More information and a better understanding are needed on the ecosystem services provided by the different types of wetlands in the Nile, and how these contribute to local livelihoods. The values of many of these services are currently unknown, as are their interactions. As a result, it is difficult to assess trade-offs between the various competing uses of the wetlands, and thus the management responses required to balance the need to increase food security while at the same time ensuring that the ecosystem services which support these activities are sustained. While many of the Nile's wetlands are inextricably linked to agricultural production systems, rapidly increasing populations in conjunction with efforts to increase food security are escalating pressure to expand agriculture within them. The environmental impact of wetland agriculture can have profound social and economic repercussions for people dependent on ecosystem services other than those provided directly by agriculture; if wetlands are not used sustainably, the functions which support agriculture, as well as other food security and ecosystem services, including water-related services, are undermined (McCartney *et al.*, 2010). The basis for making decisions on the extent to which, and how, wetlands can be sustainably used for agriculture is weak, and there is a lack of information available describing the best agricultural practices to be applied within different types of wetlands within the Nile Basin and elsewhere. There is currently a pressing need for more systematic planning that takes into account trade-offs in the multiple services that wetlands provide, and a lack of understanding on how to establish appropriate management arrangements that will adequately safeguard important ecosystem services.

Due to these information gaps, the future contribution of wetlands to agriculture is poorly understood and wetlands are often overlooked in the Nile Basin discourse on water and agriculture. While there is great potential for the further development of agriculture and fisheries within these wetlands, in particular in Sudan and Ethiopia, at the same time many wetlands in the basin are threatened by poor management practices and rising populations. Although there is potential for more agriculture within these areas, there is a need for a much better understanding of how to practice agriculture sustainably. Very few governments in the Nile Basin countries have specific wetland policies, or national strategies/policies pertaining to either water or agriculture, that make explicit reference to wetland agriculture. As a result, wetlands are influenced by the policies of many different sectors. If future wetland agriculture is to bring about net benefits a much more strategic approach to wetland utilization is required.

Wetlands can be considered natural hydraulic infrastructure, bestowing many water resource benefits, which need to be carefully considered in planning and management of wetlands (McCartney *et al.*, 2010). As any activities which affect water use and diversions of water from wetland areas have important basin-wide and downstream implications, wetland management needs to be incorporated into basin management. In addition, governance of wetlands should include a means of involving stakeholders from impacted or potentially impacted regions. A policy framework for sustainable wetlands management should include two key factors: first, the maintenance of ecological integrity of wetlands should be clearly incorporated in policies dealing with larger landscapes (e.g., river basins, provinces, etc.); second, it should incorporate a mechanism that empowers local people to manage and control wetlands in their own landscape.

Looking to the future, increased wetland use in the Nile could either lead to prosperity, or be a flashpoint for conflict. Consequently, it is essential that future wetland management should significantly improve on what has occurred in the past, and is integrated in a systematic manner into the development plans and strategies for water and natural resources in the basin.

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