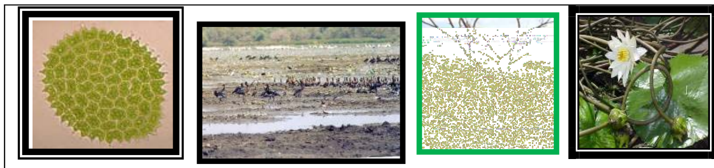
WETLANDS AND BIODVERSITY IN SUDAN



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Preface

Executive summary

Natural wetlands include river margins, natural and man made lakes, coastal lagoons, mangroves, and coral reefs, swamps, oasis, and mayas. Man-made habitats include fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans, reservoirs, gravel pits, sewage farms and canalization system.

The ecological value and significance of wetlands arises from their high primary productivity and rich biodiversity. Wetlands support a rich variety of species including numerous plants, many invertebrates, fish, amphibians, reptiles, birds and mammals. On the other hand, many species rely on wetlands for food, water, shelter and breeding. That is why Sudan ratified three RAMSAR sites. The Sudd, Dinder National Park and

In Sudan the Nile basin is divided into five sub-basins the White Nile, the Sobat, the Blue Nile, the Atbara and the Main Nile. A number of inland lakes are scattered in Sudan such lake Kundi, lake Keilak, Merri Bara, Jebel Marra Crater lake, Malaha lake, as well as a number of water pools locally known as 'Folas' in western Sudan. Lakes Kundi and Keilak are in the open *Acacia*-grass region of western Sudan. They are important watering places for various cattle-owning tribes. Both lakes show large seasonal changes in area and depth depending on precepitation. In addition, one of the largest wetlands in the world is the Sudd swamp in southern Sudan where over one million people and several million livestock live. During the long north-south conflict, these wetlands were adversely affected by uncontrolled hunting and poaching. With advent of peace, the Sudd wetlands are under pressure from development plans.

The most significant issues are major infrastructure projects related to oil exploitation, dams, water engineering projects, roads, housing schemes, conversion for agriculture and settlement, as well as resource over-exploitation by a growing population. All this points to the necessity of developing strategic action plans and building national capacity aimed at the wise use of wetlands.

If the Jonglei canal designed to bypass the “Sudd”, is completed and operated, it is expected to reduce the seasonally river-flooded grasslands. The most prone to change are the emergents. *Vossia* and *Cyperus* will retreat downstream while a substantial reduction may also be expected in the zone currently occupied by *Typha*. The seasonally flooded grasslands dominated by *Oryza longistaminata* and by *Echinochloa pyramidalis* will decrease on area by a factor between 10 and 23%.

Sudan's existing large dams have resulted in a major degradation of downstream habitats. The three impacts of most concern are reduced annual flow, removal of annual flood peaks and increased riverbank erosion. Given the cost of the dams and the observed rate of sedimentation, the economics of future dam projects in this region should be carefully examined. The protection of aquatic biodiversity is governerd by agreements on biodiversity, including the 1992 Rio Declaration on Environment and Agenda 21. The strengthening of the national capacity for water resources management and the introduction of the concept of Integrated Water Resource Management to Sudan are in harmony with several governing agreements.

The planktonic algae (phytoplankton) which live suspended in water and benthic algae which attach themselves to the bottom of the river are the two types of algal communities. All research workers focused entirely on the phytoplankton of the White Nile and Blue Nile. Benthic algae of the Nile and soil algae of adjacent wetlands and lakes were completely neglected, thus presenting a gap in knowledge which needs to be filled.

The macro hydrophytes in the Sudan range from small floating plants, to the tall reeds of the Sudd to the woody trees on river banks. They exhibit a remarkable diversity in habitats, in their vertical and longitudinal zonation, phyletism, growth forms and ecological niches. Around ninety species belonging to thirty two families are reported. The status of the aquatic plants in the Sudan reveals a situation of negligence reflected in meager studies, no attempts to utilize and no policies to conserve. The threats are: absence of scientific vision and strategic planning, pollution of aquatic habitats, introduction of alien species and conflicts.

The strategy to conserve the aquatic biodiversity of hydrophytes in the Sudan needs to be centered on the delicate balance between utilization, conservation and control. Through this perspective, a package of plans needs to be put forward. A baseline study is urgently required to survey their habitats and distribution, upgrade their taxonomy and document their known and potential uses.

The riverine forest reserves are composed of sunut forests along the Blue and White Niles and their tributaries in Dinder, Rahad and Khour Abuhabil in central and eastern Sudan in addition to the plantation of Jebel Marra and sunt plantation in Alain forest reserve in Kordofan. The riverine forests constitute less than 0.1% of the total area of the reserved forests in Sudan. They are of vital environmental and economic importance for the economy of the Sudan and in conservation of its natural resources. Moreover they provide fuel wood, poles and sawn timber for industry, construction and furniture. In addition they protect the Nile system and other watershed areas in the Sudan from flooding and erosion disasters. The wood and non–wood forest products from these forests contribute significantly to the rural livelihood, the stakeholders need to be involved in descion making regarding forests. The best studied example of wood forests is the Dinder national Park.

The Dinder National Park (DNP) is one of the oldest Parks in Africa. It was established in 1935 following the London Convention for the conservation of Africa flora and fauna. DNP is bordered by three States: Sennar, Gadarif and Blue Nile and along its eastern part the boundary gets to the Ethiopian border

DNP falls within the flat plains of the southern Blue Nile with isolated highland on the southern portion of the park. The two seasonal rivers, Rahad and Dinder, water the park during the rainy season. They descend from the Ethiopian highlands and flow a northwesterly direction across the flat plain to empty their waters in the Nile River.

The Dinder flows through the middle of the park. It starts to flow around the middle of June and ceases running in November. The sand riverbed is left with only few pools, which usually hold water up to the next rainy season. The major tributaries of Dinder River are Khour Galegu and Khour Masaweek. Other smaller streams are Kenana, Suneit, Heneifa, Abu Kkamira, Elqiser and many others. The runoff from the Ethiopian highlands usually leads to seasonal accumulation of streams that either joins Dinder or Rahad rivers. The mayas ecosystem is a very important component of Dinder National Park. It constitutes the most significance part of the dry season habitat for most of the animals in the park. Management of the mayas ecosystem requires good understanding of the hydrology of the park. It is important to keep a good monitoring program of the Maya hydrology to precede any intervention.

Invertebrates play a vital role in all wetland communities. They provide an important component in the food web, recycling nutrients and contribute to the breakdown of organic matter. They adversely impact the health of man and animal as vectors or intermediate host of parasites. The amount of invertebrates in wetland systems can vary depending on management practices. Moist-soil management produces excellent habitat for numerous invertebrates as well as for many species of birds and mammals.

Fisheries development is generally limited and is unbalanced, as most of the resources are in the wetlands of Southern Sudan, while most of the fishing is practiced in the more limited waters of central and northern Sudan.

The development of the fisheries sector for the benefit of the resource and the stakeholders requires extensive rural extension services, aquaculture and improvement of post harvest treatment.

A note on the herptiles of the wetlands of Sudan was given. It showed that there is a nedd to direct some scientific effort to capacity building in taxonomy in order to quantify our herptile fauna. This will cast light on amphibian species and their ecological role and the need for conservation of crocodiles and the Nile monitors.

The Nile and its tributaries, the Red Sea Coast, the Sudd and all inland natural and man made wetlands which attract and support important breeding population of water birds. The avifauna of Sudan numbers 938 species of which 616 are residents and 312 regular seasonal migrants, including 216 species from the Palaearctic. There are 217 species of water birds (of these 12 species live near water), of these 101 species are Palaearctic and 116 species are residents. The 217 water birds fall in 42 families. Some of these birds are of significance as game birds other contributes by their execreta in enriching plankton productivity.

The biodiversity of the different ecological zones of the Sudan is closely associated with the ecosystem productivity. As productivity depends on the association with wetlands, Savannah is characterized by high richness of mammalian species as compared with other ecological zones.

The wetland provides an important source of income, subsistence, employment and food security, and generates essential services that are unavailable or unaffordable elsewhere for the households.

Despite the high economic benefits of wetlands and the dependency of especially the poorest communities on wetland resources, economic valuation is still not a commonly applied tool in development and land use planning. Unless these values are taken into account when planning investments and land uses, it is possible to end up making decisions that are not just environmentally damaging but also economically and socially sub-optimal.

Communities with livelihood strategies that combine subsistence agriculture with utilization of wetland resources constitute a significant proportion of the population in developing countries. Their livelihood depends to a large extent on the productivity of the natural systems, in particular wetlands that provide a great variety of functions and benefits.

Prof. Zuheir N.Mahmoud Prof. Yousif B. Abu Gideiri

Khartoum, May, 2009

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WETLANDS OF THE NILE IN THE SUDAN

By
A.I. el Moghraby

1. Introduction.

The Sudan with its large area and diverse ecological and climatic zones is endowed with considerable water resources and wetland ecosystems (Fig. 1). The country stretches from barren deserts of less than 20mm of precipitation to tropical rain forests in the southwest of over 1500mm rainfall. Its flora and fauna are essentially diverse. Sudan's rapidly increasing population is also diverse in ethnic origins, languages, religions and culture.

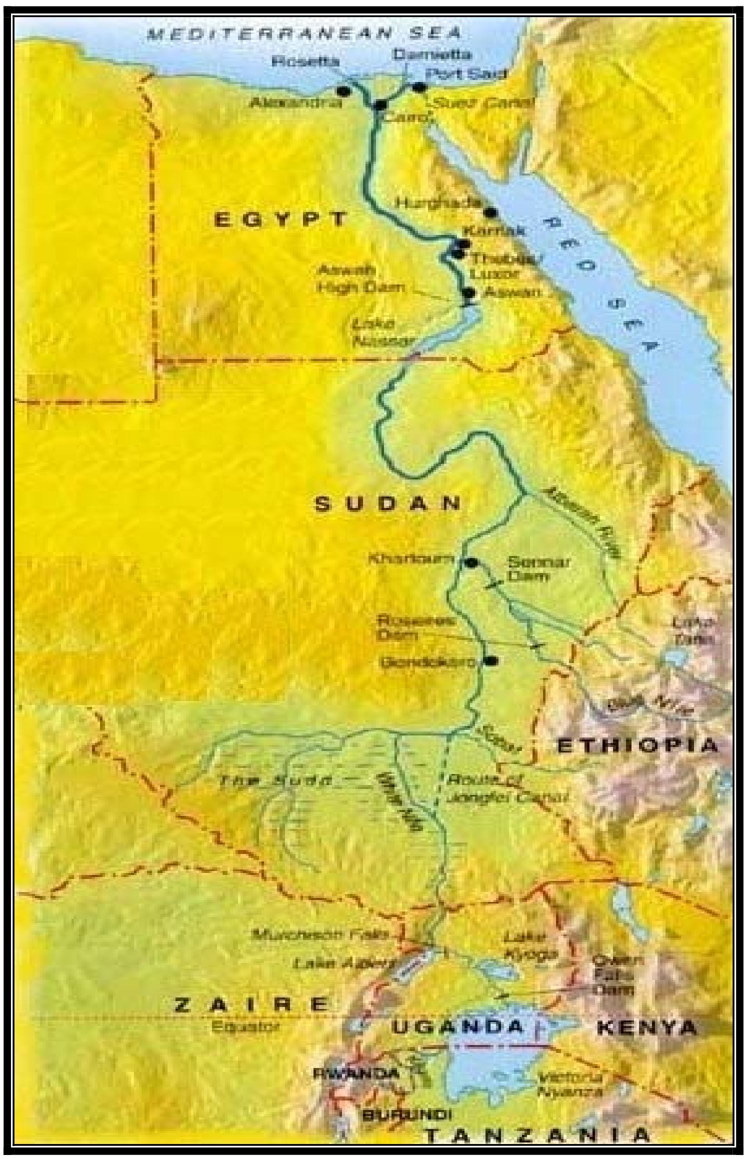

Fig. 1. The Nile basin.

Historically early civilizations flourished along major rivers of the World; more precisely around their wetlands. Basin cultivation was a major activity in the Nile until the late 19th century and it is still practiced in many parts of the basin on a smaller scale. With the escalating population pressures and increased land use conflicts and land degradation the economic importance of wetlands had resurfaced.

Wetlands are very important to those countries whose economy is mainly natural resource based. Types, sizes, systems of wetlands are quite diverse. So are the indigenous technologies to use them; as well as the need to use them for direct economic purposes. To many they are still wastelands which could only be good for conservation of biodiversity or moderate utilization as fishing grounds or reed beds. While wetlands are of the most productive of ecosystems on earth, they are also the most threatened. The importance of wetlands in the Sudan could not be overemphasized as they cover 20% of the total area of the country. They are crucial for most natural production systems, and they are national assets for development, rich sites of biodiversity, important component of drainage system and hydrology.

2. Definitions.

Over 50 definitions exist for wetlands. Wetlands are water dominated ecosystems where soils, vegetation and animal life also contribute to their unique characteristics (Roggeri, 1995). The definition adopted by the Ramsar Convention (1997) is as follows: "Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters". This broad definition recognizes five major groupings:

2.1. Marine (coastal environments),
2.2. Estuarine (deltas, tidal marshes and mangroves),
2.3. Lacustrine (lakes and associated wetlands),
2.4. Palustrine wetlands (plant dominated)
2.5. Riverine (rivers, streams and associated wetlands),

These are further divided into more than 30 subdivisions according to physical, chemical or biological characteristics (Abebe, 2003).

3. Functions and values of wetlands.

Wetlands are special habitats which have substantial ecological and socio-economic values and functions.

3.1. Hydrological values.

It is the routing effect of wetlands on the seasonal flow of the tributaries of the Nile that brings about the continuity of flow of the main streams. A striking example is the Machar Marshes. These receive floodwaters of the Baro, Akopo, and the Bibor as well as the "sheet flow" of the local rains and a substantial flow from numerous torrential rivers of Ethiopian origin. These waters flow slowly across many channels, bogs and marshes only to reach the White Nile long after the rains have passed.

Similarly the Ethiopian wetlands slowly release stored water into the many tributaries of the Abbay (Blue Nile), long after the copious rains have ceased to fall. It should be remembered that Lake Tana is responsible for only 7% of the annual discharge of the river. The Sudd as a unique wetland will be dealt with in chapter 2 of this edition titled Ramsar wetlands of the Sudan.

3.2. Economic values.

Wetlands have direct values such as production and consumption of goods and services (fish, water, medicinal, raw materials), and indirect values such as ecosystems functions and services such as: water quality, flood control, and nutrient retention, etc. They also provide a wealth for non-consumptive values e.g. cultural, aesthetic and heritage values. Wetlands make significant contributions to poverty alleviation as they cut across the traditional sectors.

Stabilization of water flow, control and improving water quality, provide a source of water and grazing for livestock and wildlife. It is a rich habitat for breeding, rearing and survival of fish. It is a winter habitat for various migratory birds and wildlife. It is home to some endemic wildlife and fish species. Perhaps around 80% of the Sudanese, mainly with a nomadic or trans-humans pattern of life, depend on their subsistence on the seasonal patterns and dynamics of productivity of wetlands.

3.3. Social and Cultural Values.

In parts of the Sudan like the Upper Nile, during periods of low flow, the wetlands are a social center for initiation of relationships and dancing leading to courtship and marriage. Wetlands sustain the livestock used as dowry in marriages, religious rituals and payment of penalties. Furthermore wetlands contain some wildlife species considered by the Nilotes to be sacred. These include the Nile Lechwe (*Ontragus megaceros*), the Shoebill Stork (*Balaeniceps rex)* and the Crowned Crane (*Balearica pavonina*).

4. Overview.

The Nile Basin Initiative estimated that "about three percent, of the area of the Nile Basin is covered by wetlands, compared with two percent of forest and 1.4% irrigated cropland" (NBI, 2001). In the Sudan there are at least 26 distinct types of wetlands ranging from rain pools to crater lakes, from natural to man-made and from protected to threatened. They cover about 20% of the total area of the country while forests cover only 12%. It must be stressed that the Ramsar classification of wetland type, currently in use, was not adopted (categories and subdivisions of which give a total of 40 wetland types).

To date wetlands, in the Sudan, are not even recognized as a distinct landform. There is no inventory of their locations, types, status, ecology and socio-economic values, capacity and potential. As a matter of fact wetlands are threatened with habitat.

Due to their socio-cultural and economic importance these water dominated habitats have many local names including: rahad, turda, khor, waddi, mayaa, botta, idd, rigil, eid, ein, kalgaia, fula, saraf, farresh, tabb, lissan, khalgia, mashesh, birka, gulta, lissan, sabkha and shura etc.

5. Wetlands of the Sudan.

5.1. Natural Wetlands

5.1.1. Rain pools.

An average of 1250 $x10^9$ m^3 per year of rain falls over the area of 2.5 x 10^6 km^2, which make the Sudan. The rainy season is short and variability is high. Runoff in the clay plains induces "sheet flow" (or "creep flow"). Depending on topography and relief precipitation collects into 'khors' and "waddis", tributaries, streams and river channels. More than often water collects in rain pools. They come in all sizes, volumes and shape. Water harvesting is not advanced nor is it an efficient indigenous practice.

Life in those rain pools (Fig. 2) is rich and diverse (Rzoska, 1961). Lifecycles are short and fast.

Fig. 2. A rain pool.

5.1.2 Seasonal streams (Khors):

These are fast flowing and laden with silt. They transport nutrients to larger water bodies. They are widely distributed all over the country, the largest of which is Khor Abu Habil draining the Nuba Mountains and contributing to the economy of northern Kordofan. The khor probably harbors the largest population of the lung fish *Protopterus annectens annectens.*

5.1.3 Seasonal rivers.

Seasonal streams and rivers are numerous; Atbara, Rahad, Dinder, Gash and Baraka are among the largest. During the dry season pools may remain on dry river beds. They are important watering sources for man and wildlife. They are important breeding grounds for fish, reptiles and birds. The flora and fauna of those systems expand and contract depending on the intensity of rains. They interconnect during extremely wet periods and get isolated during drier ones.

The non-Nilotic streams in the Sudan are 44 in number and are responsible for providing $7x10^9$ m^3 of water per year.

5.1.4 Mountain streams (Fig. 3).

Khor Arbat in the eastern Sudan, Wadi Gallol in Darfur and river Gilo in the Imatong Massif in southern Sudan are examples of perennial mountain streams. A smaller stream, in the Ingassana Hills (Sarraf Jam) in the Southern Blue Nile, originates at some shallow springs and loses itself four kilometers downstream. They are all rich in invertebrates and fish.

Wadi Galol in Jebel Marra was the home of 16 species of fish, nine of which are found in the Nile. The others were of West African origin (HRU, 1965). They all disappeared during the 1984 drought when the stream dried up completely.

Fig. 3. A mountain stream.

5.1.5 The Nile.

The Nile is the largest river in the world. Its basin (2,978,000 km^2) occupies nearly 10% of the land surface of Africa continent. The Nile basin consists of five sub-basins running into two main tributaries, the White Nile which flows 2,000 km, from the central African plateau, and the Blue Nile which flows from the Ethiopian plateau to join the White Nile in the Sudan plains at Khartoum. The Joint River flows northwards for a further 3,000 km, through five cataracts, before it flows into the Mediterranean. The Nile is the only tropical river to reach the Mediterranean (Fig. 1).

5.1.6 Freshwater lakes.

Examples are Er Rahad, Kundi, Keilak and Abyad, in western Sudan; Ambadi, Yirol, Nyiropo, in Southern Sudan. They are rich in biodiversity especially microinvertebrates and water fowl (Green *et al.*, 1984).

5.1.7 Seasonal lakes.

These are found in different regions and include Um Badir, El Fula, Ras Amir, Um Baggara, Kibbew, Undur, Nzeli, etc.. (Moghraby, 2001).

5.1.8 Crater lakes.

Two volcanic lakes are found in Jebel Marra (Dariba, Fig. 4) and Malha (Fig. 5) in the Medob Hills. They are all saline. Only the shallow Dariba lake is rich in biodiversity (Green *et al.,* 198--).

Fig. 4. Dariba Lake (Jebel Marra)

Fig. 5. Malha Lake (Meidob Hills)

5.1.9 Hot Springs.

Perhaps Akasha hot springs, at the tail of Lake Nubia are the most accessible. Others are found in Quella (Jebel Marra), el Harra (wadi Azum) and in the Meidoub Hills.

5.1.10 Oasis**.**

They are 67 in number in the western desert, six of which are inhabited by nomads. Two have schools and medical facilities. Around 15 to 17 have high water tables. None still hold open water.

The Nukhaila Oasis is the only open water relicts of the wet Holocene period, found in this part of the World. It is located in the extreme north western part of Darfur and is distinguished by the presence of a Lake having an area of 800 x 300 meters. Its water is of moderate salinity. The Lake, in spite of its salinity and its location is showing interesting biodiversity presenting savanna species. The presence of the rear aquatic crustacean *Artemia artemia* deserves special mention. Unfortunately it is subjected to sand encroachment at an estimated rate of 4 m/year (Nimir, 1998).

Selima Oasis, some 600 km northeast of Nukhalia, has a low biodiversity due to its small water body (Prof. Z. N. Mahmoud, personal communication). Some other water sources on the historic camel route, 'Darb al Arbain', have dried up. They include Lagiya Arbain and Lagiya Urman. The Lagiyas fall in a depression that runs in a south/north axis, parallel to the Nile valley.

Atroun Oasis is a marine relics found in north Darfur (Fig. 6).

5.1.11. Al Gaab.

In investigating the potential of the Nubian Aquifer for irrigation, several test boreholes were dug in the Gaab depression (Gaab el Grood*:* 19º 02¯25= N -29º 51¯46= E- elevation 250masl; about 60km west of the city of Dongola). Water from the artesian basin, flow under pressure (Fig. 7) and led to an enormous wetland with typical swampland vegetation, exclusively *Phragmites, Typha* and *Echinocloa* spp in addition to sessile algae.

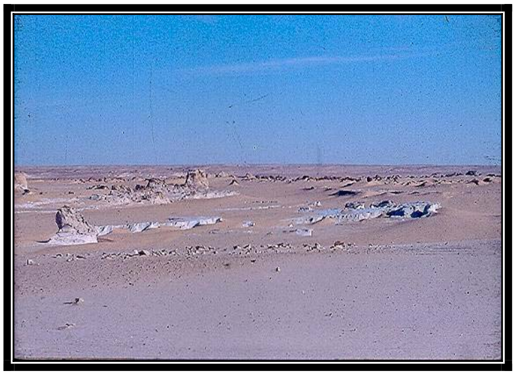

Fig. 6. Atroun Oasis.

Fig. 7. Al Gaab.

5.1.12. Mayyas

These are wet meadows and old ox bow lakes. They are an important source of water and fodder in the long dry season. They are either fed from rivers or by sheet flow or both. They frequently border torrential rivers like Dinder and Rahad (Fig. 8). El Sleim and Khaowi 'basins', between the third and fourth cataracts of the River Nile, are among the largest and most productive agricultural areas in the Sudan.

5.1.13. Sunt Forests

Although sunt forests are adequately covered in chapter 4 this addition, one wetland deserves special mention. It is the Khartoum Sunt Forest which is located at the confluence of White Nile and Blue Nile or 'Mogran' The Mogran area is also the location of White Nile Birds Sanctuary (established in 1939). The Sunt Forest sustains large populations of sedentary and migratory water fowl and other bird species (120 migratory species visit the Sudan, which includes 89 water fowl).

5.1.14. Flood plain

Since times immemorial the Nile Valley flood plains (Gerif) have been cherished because of their high agricultural productivity due to regular silt-laden flood. The waters of the Blue Nile, for example, rise by an average of four to seven meters above the low flow period. Depending on topography the flood plain could be several kilometers wide (Fig. 9).

Fig. 8. A mayaa in the Dinder National Park

Fig. 9. A flood plain.

The flood plains are also important as feeding grounds for water fowl and for breeding and nesting for fish.

Productive agricultural land is utilized along the banks of the Niles and main source of dates, vegetables and cultivated fodders. Large schemes growing broad beans, wheat and lentil are found in Northern Sudan. El Sleim is a fore runner. Wadi el Mugaddam, Wadi el Milk and el Bashiri Oasis are large Government driven agricultural schemes.

5.1.15. Ground water.

The ground water resources of the Sudan are in the region of 900×10^9 m^3 (Fig. 10).That is more than a 100 times the annual flow of the Nile. The annual recharge is around four billion and the annual consumption is around 1.2 billion meters cube (Moghraby, 1993). They are found in basins including: Nubian Sahara Basin, Nubian Nile Basin, Um Kaddada Basin, En Nuhud Basin, Geddarif Basin, Blue Nile Basin, White Nile Basin, Baggara Basin and the Sudd Basin. This resource is tapped by shallow wells, tube wells and bore holes. It is sometimes used for irrigation.

The irrational attempts to develop this resource in the early 1960s triggered off the massive degradation of the marginal lands of Kordofan and Darfur. What was known as the "Anti-Thirst Campaign" accelerated rates of desertification by exceeding the carrying capacity of land around the water points established.

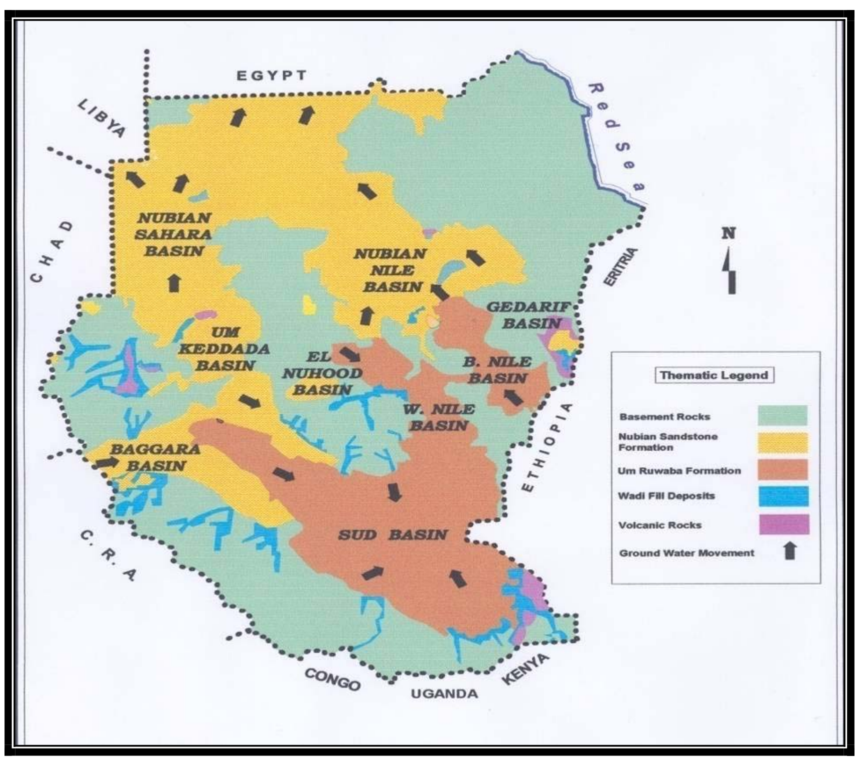

Fig. 10. Ground water basin in Sudan (Source: EDS-1999).

5.2. Man made Wetlands

5.2.1. Haffirs

Man-made wetlands include the Haffirs which are widely spread in Kordofan, Darfur, Kassala and the Blue Nile. More than two thousands large Hafirs have been constructed over the years. The Haffirs use water harvesting techniques through excavation of natural depression sites of low permeability for storage of rain water. Haffirs are usually constructed in areas with no permanent sources of surface or ground water. They vary in size and holding capacities. They are usually not lined. Haffirs have been used for thousands of years in the arid Butana plains of central Sudan and the rulers of the ancient kingdom of 'Kush' used the extensive network of haffirs as a means of controlling nomadic populations and for collection of taxes.

5.2.2. Burrow pits

Untold numbers of burrow pits have been excavated during the start of the construction of the interstate network of highways. A few of them hold water all year round. They were a welcomed additional source of water to man and beast during the long dry seasons. Their profound effects on the local ecology and socio-economic systems are readily felt. Never the less they are a source of water related diseases not mentioning the risk of drowning, having not been purposely constructed.

5.2.3 Barrages and small dams:

These are numerous in many parts of the country, more so in the southern wetter parts. Small dams in Equatoria Province include those at Yei, Maridi, Yambio, Anzara, Ezo andLi-yu-by. Welands behind them hold a tremendous potential for fish farming (Bishai, 1962).

5.2.2. Dams on the Nile in Sudan

New reservoirs have important effects on the ecology of rivers. Deoxygenation of water from the rotting of drowned vegetation. The increased organic content of water appears to be in favour of the development of floating water plants in the early years of inundation. An increase in fish populations is one of the major results of inundation. Species of fish preferring sluggish, stagnant waters show an immense increase in numbers compared with species which prefer swiftly flowing current.

A hazard to people living near newly created reservoirs is altering the ambient physical conditions thus affecting the intermediate hosts of human diseases. Malaria, onchocerciasis, schistosomiasis and kala-azar may be propagated. Lewis (1957) found that the reservoir at Jebel Aulia created an excellent breeding site for *Anopheles gambiae*. In Sennar reservoir *Echincloa stagmina* formed grass mats on silt deposits.

Plans for future dams on the River Nile were discussed at different levels.The Eastern Nile Subsidiary Project (ENTRO) of the Nile Basin Initiative (NBI) under the Power Trade Investment Programme investigated the feasibility and priorities of the construction of new dams and dam sites in the four countries of ENTRO. Sudan and Ethiopia offered many opportunities. It was decided that the priority goes to building four dams on the Blue Nile in Ethiopia, where evaporation is one eight of that in the

Sudan. The depth to surface area ratio is also more favourable. This approach is novel and it is for the first time in the long history of development of the waters of the Nile that this trans-boundary outlook is entertained. Some hot issues like the need for a master plan for the whole Nile Basin, the evaluation of status and/or benefits of other dams (particularly Roseires and Khasm el Girba), the problem of sedimentation need to be addressed.

Following British control of key countries of the Nile Basin, major hydrological investigations were undertaken to try to devise methods of controlling the river system in order to facilitate its exploitation. The seasonal variation has posed a key challenge to river basin planners and agriculturalists alike: how to capture and store the river's waters for more gradual release.

During the 20th century the flow of the Nile has been increasingly brought under control by means of dams, which inevitably altered the hydrological regime of the river and contributed to substantial limnological impacts.

Some of the characteristics of those dams are listed in Table 1.

Table 1. Dams in the Sudan and their characteristics

Name	Sennar	Jebel Aulia	Khashm el Girba	Roseires	Meraowe
Year of construction	1925	1937	1964	1966	2008
Designed Capacity m^3	$930x10^6$	$3.5x10^9$	$1.3x10^9$	$3.0x10^9$	$12x10^9$
Length of Reservoir km	80-96	400	80	75	200
Electricity MW	15	30	7	189	1250
Area of reservoir km^2	160	600	150	290	
Altitude mASL	422	377	473	480	
Depth m	17	15	20	50	

Plans for future dams on the River Nile include:

The Eastern Nile Subsidiary Project (ENSAP) of the Nile Basin Initiative (NBI) under the Power Trade Investment Programme investigated the feasibility and priorities of the construction of dams and dam sites in the four countries of ENTRO. Sudan and Ethiopia offered many opportunities (Table 2).

Table 2: Some characteristics of proposed dams

Dam	FSL m	Dam height (m)	Installed capacity MW
Border	El. 575	84.5	1400
Mandaya	El. 741	164	1620
Mabil	El. 906	113.6	1200
Dal	El.218/201	45 / 20	780/340
Kagbar	El.218/213	17	300/108

This approach is novel and it is for the first time in the long history of development of the waters of the Nile that this trans-boundary outlook is entertained. Never the less, there are some serious departures. The narrow, shortsighted, national, mono-disciplinary way of thinking still prevails. The Sudan is acting outside the umbrella of the NBI. There is a need a need to evaluate the performance of Kashm el Girba dam, monitor of relocation of the Nubians in New Halfa, the attitude of the local people should be respected and archeological value of "al Dofof" of Karma, 7000 years old and Kadrouka, 9000 years old) should be considered prior to construction of Kagbar and Shreik dams.

5.2.3 Irrigation Canals

The oldest intensive network of canals in the Sudan conveys water from Sennar Reservoir onto the Gezira and Managil Schemes. The main canals are each 20 meters wide. The lower ends of the network are the minor canals which are effectively stagnant pools of water. The Gezira scheme alone has over 10,000 km long canals. The canals are artificial wetland habitats for aquatic species of flora and fauna. The sedimentation and the profuse spread of aquatic plants and vectors of bilharzias and enteric diseases are common requiring regular dredging of canals, so that irrigation water conveyance is not impeded.

Other vast canalization network include those of Rahad, Suki, New Halfa, Geneid, Assaliya, Sennar, Kennana, Blue Nile and White Nile pump schemes.

5.2.4 Irrigated Areas

The Sudan has an arable area of more than 200×10^6 feddans, 2% of the growing seasons are summer and winter.

6. Economic values of wetlands:

The economic importance of the wetlands and patterns of use show a lot of diversity, culture (indigenous knowledge) and the need for the resources. In some parts of the country wetlands are even avoided in agricultural development and are considered bogs with poor local relief. In other parts e.g. the southern Sudd, the rhythm of life follows that of the rising and falling level of wetlands.

Lands along the banks of the three Niles are the main source of dates, vegetables and cultivated fodders. Large schemes growing broad beans, wheat and lentils are found in Northern Sudan. Khor Abu Habil, Al Gash and Baraka are the lifeline arteries of their regions. Fishing and basin cultivation are important economic practices in the Nile reservoirs while *Acacia nilotica* "Sunut" forests of the Blue Nile are of the few success stories of forests management in the Sudan (Moghraby, 2001).

Socio-economic and cultural patterns and way of life of nomadic or transhumant tribal groups all over the Sudan are dictated and governed by patterns and dynamics of productivity of wetlands. In urban centers brick making for buildings is practiced along the Nile and its tributaries where deposits of sediments are used and are usually replenished by the annual floods.

The wetlands ecosystems and their adjacent riparian habitats perform, in terms of goods and services, important ecological functions as source for water resources, flood storage, erosion control and sediment trapping.

7. Wetlands and biodiversity:

The Higher Council for Environmental and Natural Resources (2001) produced Sudan Country Study on Biodiversity which considered wetlands as a crucial element for biodiversity conservation. The biodiversity components assessed were range and pasture, forestry, livestock, coastal and marine life, agricultural biodiversity, the upper Nile swamps, the man-made aquatic environments, wildlife, agricultural arthropod pests and Nile fish. Wetlands conservation was identified as the most important issue in the sustainable management of biodiversity in the Sudan

The low elevation and the prevalent high temperatures have resulted in the fact that potential evapo-transpiration is higher than actual precipitation in most parts of the country at most times of the year. The recurrent droughts of 1968, 1974, 1983-1985 and early 1990s had intensified the role of wetlands as biodiversity hot spots within the different ecosystems.

8. PROBLEMS OF WETLANDS IN THE SUDAN

Sudan diverse systems of wetlands are subjected to different problems due to ineffective management approaches and practices. These problems included:

8.1 **Threats**

- Lack of understanding and appreciation of the various values of wetlands could only result in inadequate planning, poor land use policies, conflicting land use practices, ineffective management and ineffective law enforcement. The most important threats are briefly enunciated:
- Wetlands are neither acknowledged as a distinct entity nor the distribution and extent of wetlands has not been documented in detail.
- Wetlands have not been classified by type, size or pattern of use.
- The traditional and present uses of wetlands have not been outlined.
- The potential of wetlands in sustainable development and poverty alleviation has not been recognized.
  - Loss of vegetation covers and increased sedimentation locally and regionally.
  - Horizontal expansion of agricultural practices in wetland and surrounding areas.
  - Issues related to wetlands management are dealt with as secondary issues when addressing agricultural development and related activities.
  - Lack of participation and coordination with important stakeholders.
  - Lack of effective legislation, and law enforcement.

8.2. Potential eco-disaster.

Potential eco-disasters are exemplified by projects in the most vulnerable wetlands of the Sudan. These are Jonglei canal and oil exploitation.

Recent climatic variations and consequent fluctuations of annual volumes of discharge of rivers in the Nile Basin, suggest that assumptions adopted around the mid-20th centaury regarding the availability of water may now require drastic reassessment. Decreasing rainfall in many parts of Africa brought about a drop of water levels in many African Lakes. For example Lake Turkana shrank from within the Sudanese borders and the level of Lake Victoria dropped by nearly 2.5 m. Therefore increasing the efficiency of water use is the right step in the right direction.

Petroleum prospecting drilling and transport in wetlands is causing problems of pollution mainly due to road construction and the inadequate disposal of the "produced water. Intoxication of the ecosystem by binding chemicals sprayed in roads. Large scale deforestation is practiced for the right of way of roads, pipelines, transmission lines, and for the unchecked production of timber, firewood and charcoal. Poaching is widely practiced. Violation of local cultures. Sensitive areas in relation to breeding, nesting roosting and migration, of fish and wildlife, have been distorted beyond recognition

Waste resulting from solid waste and garbage, sanitary effluents and drilling wastes are improperly managed.

The disposal of produced water poses special problems to the oil industry as 600,000 barrels of water are produced every day at Heglig CPF alone. Moghraby (2006) suggests safe disposal and not storage in ponds as is happening now in Heglig.

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Chapter 2. Ramsar Sites Associated with the Nile in Sudan.
Part I. The Sudd
By

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1. Introduction

The wetlands of Southern Sudan are extensive and spread across the ten Southern Sudan States. The most notable one is the Sudd swamp now known as a Ramsar site. Other important wetlands not along the Nile basin but are of immense importance to the rural populace include: Lakes Yirol, Anyi, Nyiropo, and Maleit, Ibba, Maridi, and Lau rivers, Lotagipi, Kidepo valley, Machar marshes, Lotila, Veveno, Adiet and Lilebook, Joum swamp, Badingilo, Chol, and Atundi swamps to mention a few. In June 2006, the Sudd swamp was listed as wetlands of international importance under the Ramsar Convention. The Ramsar convention is an intergovernmental treaty that provides a framework for national and international cooperation for the conservation and wise use of wetlands. The convention restrains member countries from unsustainable use of their wetlands.

2. The Sudd Wetland

The Sudd (Arabic means barrier) is a vast swamp formed by the White Nile here called the Bahr-el-Jebel in Southern Sudan. The Sudd is one of the largest wetland in the world (Peterson, 2008), and is the largest wetland in Africa. Its size is highly variable, average with 30,000 km^2 and may, during the wet season be over 130,000 km^2 depending on the inflowing waters, with the discharge from Lake Victoria being the main control factor of the flood levels, and areas inundated.

The shallow and flat inland delta between 5.5Nº and 9.5Nº covers an area of 500 km^2 south to north and 200 km^2 east to west between Mongalla in the south and Malakal in the north (Fig. 1).

The Sudd swamp is a unique extensive nature reserve that provides bounty to all kinds of animals including man. It provides rich and varied habitats for a variety of fish, mammals, birds, reptiles, amphibians, and invertebrate species as well as contributing to food security by alleviating poverty of the Dinka, Nuer and Shilluk communities that inhabit the Sudd flood plains.

The Sudd wetland and its flood plains are sources of fish, meat and skins from wildlife, traditional medicines from various plants species, famine food reserve and water for humans, livestock and plant species, constructions and building materials, providing opportunities for transport and are important dry season grazing areas.

Fig. 1. The location of the Sudd Wetland in relation to the Nile Basin countriesa

The Sudd is fairly located in the central part of Southern Sudan where it borders Lakes State in the southwest, Unity State in the northwest, Upper Nile State in the northeast, Jongolei State in the southeast and Central Equatoria State in the south. It lies between the towns of Bor (Jongolei State) in the south and Malakal (Upper Nile State) in the north at latitudes 7º 34^{-} 009$^{=}$ N and 29º 30^{-} 39$^{=}$ E (Figs. 2 and 3).

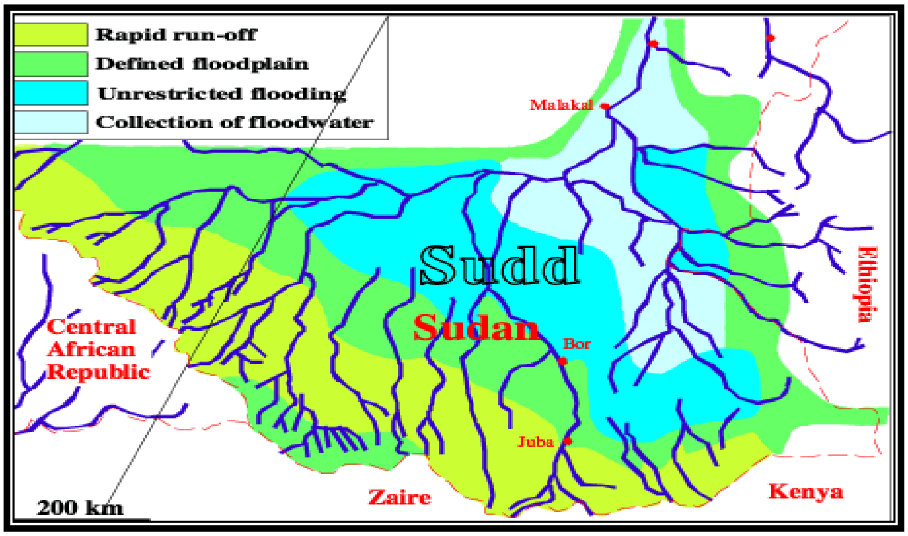

Fig. 2. The location of the Sudd wetland and associated flood plains (Source: Powell and Lock, 1994).

Fig. 3. An aerial overview of the Sudd wetland.

3. Biodiversity of the Sudd wetlands.

The landscape is mainly very flat grassland and rises very little towards the east that supports some tree species. The geology of the area is defined by heavy clay soils, highly impermeable with atop layer of black cotton of approximately 500 mm. in average. Sandy soils are found only in depth of approximately 30 m. and bellow, referring to the well drilling profiles (Peterson, 2008). This indicates a very little ground water influence on area hydrology.

3.1. The flora.

The vegetation of the Sudd consists mainly of expansive papyrus (*Cyperus papyrus*) swamps where the Nile changes direction and splits into tributaries. The plant biota grades from submerged and floating vegetation to swamp dominated by *Cyperus papyrus,* P*hragmites* (reeds), *Typha and Vosia cuspidate* swamps which are important habitat for shoebill stork. The water surface of the Sudd is covered with green plants of huge blankets of floating islands of soft wooden stems of *Aeschynomene elaphroxylon* that rise above the water surface. Seasonal grass flood plains are dominated by wild rise *Oryza longistaminata, Echinochloa pyramidalis, E. stagnina* as well as *Hyparrhenia ruffa* at the edge of the wetland. Results by UNEP (Jan. 2007) Sudan Post Conflict Assessment Report indicate that over 350 plants species were identified including *Suddia sagitifolia* an endemic swamp grass in the Sudd wetland.

3.2. The fauna.

According to the UNEP (2007) over 100 fish, 470 birds, more than 100 mammalian species have been recorded in addition to unknown diversity of amphibians and reptiles.

Wild animals were hunted by local people in the past as an important food source using traditional weapons, but with the availability of modern weaponry the current status of large mammals including elephants urgently needs to be reassessed. The Sudd used to be home to the northern white rhinoceros (*Ceratotherium simum*) now believed to be locally extinct. However, sporadic reports from patrol rangers say there were some occasional sightings of the white rhino but this needs to be verified.

Large mammalian species that utilize the Sudd and its flood plains are the endemic Nile lechwe (*Kobus megaceros*), the resident sitatunga (*Tragelaphus spekei*), hippopotamus (*Hippopotamus amphibious*), and the seasonal migratory species of the endemic white eared kob (*kobus kob leucotis*, Fig. 4), tiang (*Damaliscus lunatus*) and Mongalla gazelle (*Gazella rufifrons albonotata*), buffalo, waterbuck, bushbuck and oribi that utilize the flood plains grassland together with livestock during the dry season.

Fig.4 . White eared kob migration into the Sudd wetland during the dry season (Source: P. Elkan and J. M. Fay).

Before the prolonged civil war, the most abundant large mammals were the elephant (Fig.5), tiang, white eared kob, Nile lechwe, and sitatunga; hippopotamus, and Mongalla gazelle.

Fig. 5. A herd of elephant in the Sudd wetland (Source: P. Elkan and J. M. Fay).

Large crocodile population and the biggest population of Shoebill stork *Balaeniceps rex* in the World. Aerial survey recorded 6,407 individual shoebill storks (UNEP, 2007). Hundreds of birds' species use the Sudd as a stop over on migration. Migratory species include the endangered black crowned crane *Balaerica paronia*, white pelican *Pelecanu onocrotalus* and white stork. Other birds found here are the two endemic species called the River prinia (*Prinia fluvialis*) and the Fox's weaver (*Ploceus spekeoides*) WWF (2000).

5. Economic value of the Sudd wetlands.

The services and goods provided by the Sudd wetlands are diverse including non-consumptive such as photosynthesis, water source; optional values such as new medicines that can be discovered in the future from some components of the biota; the existence the Sudd wetland itself (existence value). All these are values can hardly be quantified in term of money. The Sudd wetlands provide:

5.1. Settlement.

The live of a large sector of the Nilotics (Dinka, Nuer and Shiluk) is associated with the Sudd wetlands as they settle there (Fig. 6). It provides them with food (fish) and fodder for their animals. The rural populations of Southern Sudan depend directly on natural resources and wetlands for their livelihood, but poverty frequently exacerbates/increases natural resource degradation by forcing the poor to utilize these resources unsustainably thereby leading to resource scarcity resulting to tensions, competition and/or conflicts remain inevitable in the absence of proper management and guidance.

Fig. 6. Vegetation destruction associated with settlement

The communities living in and around the Sudd swamp are agro-pastoralists and fishermen. Their main activities include:

5.1.1. Livestock.

The wealth of the Dinka and the Nuer of the Sudd wetland is measured in terms of livestock. It is estimated between 2.5 to 4.5 million heads of cattle, sheep and goats are reared in Jongolei State alone.

5.1.2. Fishing.

Apart from other activities the three main Nilotic ethnic groups; the Dinka, Nuer and Shilluk also depend heavily on fish for food and household income cash. Fishing territories are communal and territorially managed and controlled by clans. Over 100 fish species are being harvested using traditional methods. Discussions with the Principal of the Fisheries Institute at Padak (Feb, 2007) revealed that over 400,000 tons of fish are harvested annually in Jongolei State.

5.1.3. Poaching

Generally, hunting is banned in Southern Sudan; unfortunately it is difficult to eradicate poaching. The Ministry of Environment, Wildlife Conservation and Tourism is mandated to control poaching and the State Governments has made it as a policy to report any activity unauthorized in protected and unprotected areas.

5.1.4. Agriculture

Crop production is one the traditional sources of subsistence farming considered by the local communities as important as livestock breeding. The crops cultivated are sorghum, maize, millet, groundnuts, beans, simsim and tobacco. The land is also suitable for other crops such as sugar cane, rice, cotton, etc.

5.1.5. Firewood collection and charcoal making

Collection of fuel wood from dead trees is an environmentally friendly day to day practice. Charcoal as a recognized rapid source of high income will make deforestation in inevitable.

5.2. Potential for Ecotourism Development

It has several falls including the Fulla Rapids at Nimule (proposed site for hydroelectricity). These potentials also range from the wildlife for example, tiang, white eared kob and Mongalla gazelle, and the great bird concentration along the River Nile and the Jongolei-Upper Nile flood plains.

In its different micro-ecosystems there are fascinating areas with unique and endemic mammals, birds, reptiles, fish and plant species some of which have not been discovered scientifically but are known by the local people.

6. Threats to the Sudd wetlands

Most wetlands globally face serious degradation due to the ever increasing human population, and since many people still regard wetlands as idle lands, waste lands, lands of menace (malaria, bilharzias etc), wetlands are faced with enormous threats ranging from encroachment and consequent disappearance to regarding it as a sites for wastes (solid and liquid) disposal.

The Sudd wetlands of the Sudan are threatened by:

6.1. Oil exploration, extraction and the associated produced water and hazardous wastes.

6.2. Soil degradation due to construction of access roads (Fig. 7), spray of oil and binding chemical, domestic effluents and solid wastes (plastic). The roads are a source of dust and associated chest problems, potential accidents and nuisance to breeding and nesting animal.

Fig. 7. An access roads within the Sudd wetlands

6.3.Water pollution from oil exploration, extraction and from domestic effluents from residential camps as well as from the local people (Fig. 8).

a b

Fig. 8. a and b. The local can pollute the ecosystem

6.4. Poaching and commercial hunting and charcoal production.
6.5. River bank degradation, soil erosion, siltation and sedimentation.
6.6. The Jongolei canal project with all the anticipated negative impacts on the Sudd wetlands and its inhabitant.

7. Government attitudes towards the wetlands.

The vision of the Ministry of Environment, Wildlife Conservation and Tourism (MEWC&T) of the Government of Southern Sudan (GOSS) is to protect, preserve, propagate, manage and sustainablity utilize the flora and fauna of Southern Sudan for the present and future generations as stipulated in the Southern Sudan Interim Constitution of 2005.

The Ministry is invested with the mandate to ensure that the environment of Southern Sudan is protected against harmful human activities such as wildfires, prevent pollution, ecological degradation and any natural hazards and to promote conservation and secure ecologically sustainable development and the wise use of natural resources while promoting rational, economic and social developments so as to protect genetic stability and biodiversity of Southern Sudan.

The prime goal is to enhance the wise use of the Sudd wetland to sustainably improve the livelihood of the communities living within the Sudd wetland and/or dependant on it for some time of the year. Thus conserving biological diversity of the Sudd, the sustainable use of its components and the fair and equitable sharing of the benefits arising from out of the utilization of genetic resources, species and ecosystems is a novel objective. For the fulfillment of these objectives there is a need to:

7.1. To carry out inventory of all wetlands in Southern Sudan.

7.2. To document the richness of fauna and flora.

7.3. To identify the best biodiversity conservation programs and activities.

7.4.To carry out detailed assessment of ecological, socio-economic, cultural and other values and functions of prioritized or selected areas for short and long term purposes.

7.5. To disseminate information on values, threats and conservation plans in order to protect, conserve, manage and develop wetlands and biodiversity.

Although the Department of Wetlands and Biodiversity (Directorate of Environment in the Ministry of Environment, Wildlife Conservation and Tourism) has trained, qualified and/or experienced staff, it lacks scientific material and financial support to carry out its duties. Apart from the swamp ecological studies carried out in the 1980s and verbal reports by game rangers and the Environmental Assessment Report by UNEP (Jan. 2007) no detailed studies have been conducted specifically on the Sudd swamp and its biodiversity.

Conclusion

The interests of all members of the community are similar, and are basically in line with sustainable management of natural resources. Communities have lived with natural resources 'since time immemorial' and therefore have a detailed insight in how the ecosystem works. An indigenous knowledge and management system exists that is superior to that of the imported managers. Once 'mobilized and sensitized' community members will realize their folly of unsustainable use, and will happily embrace the sustainable use concepts

Recommendations

This paper recommends that there is a need to:

1. Carry out inventory of all wetlands in Southern Sudan.
2. Carry out inventory of the Sudd swamp natural resources.
3. Identify key stakeholders and carry out stakeholders analysis.
4. Launch a vigorous awareness and sensitization campaign through consultative meetings with a wider stake holders and resource users of the Sudd wetland.
5. Form component committees of resource users of the Sudd wetlands
6. Set a management plan for the Sudd swamp and other wetlands

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Chapter 2. Ramsar Sites Associated with the Nile in Sudan.

Part II. Management of "Mayas" Ecosystem in Dinder National Park

By

Dr. Mutasim B. Nimir and A. O. Eljack

1. Introduction

Dinder National Park (DNP) is one of the oldest Parks in Africa. It was established in 1935 following the London Convention for the conservation of Africa flora and fauna. DNP is bordered by three States: Sennar, Gadarif and Blue Nile and along its eastern part the boundary gets to the Ethiopian border

DNP falls within the flat plains of the southern Blue Nile with isolated highland on the southern portion of the park. The two seasonal rivers, Rahad and Dinder, water the park during the rainy season. They descend from the Ethiopian highlands and flow a northwesterly direction across the flat plain to empty their waters in the Nile River (Fig. 1).

The Dinder flows through the middle of the park. It starts to flow around the middle of June and ceases running in November. The sand riverbed is left with only few pools, which usually hold water up to the next rainy season. The major tributaries of Dinder River are Khour Galegu and Khour Masaweek. Other smaller streams are Kenana, Suneit, Heneifa, Abu Kkamira, Elqiser and many others. The runoff from the Ethiopian highlands usually leads to seasonal accumulation of streams that either joins Dinder or Rahad rivers.

The climate of the Park is characterized by two seasons: the hot and the humid rainy season (May- November) and cool dry (December- April).

The northeastern part 0f the Park has least rainfall (600- 800 mm), which gradually increases with distance towards the southeast of the Park (800-1000). In 2001 the Dinder National Park Project DNPP installed a meteorological Station. Before the installation of that Station and rain gauges in several locations in the Park the amount of rainfall of the Park were estimated based on the rain fall of the nearest meteorological station In Damazin and Gadarif and Singa. Table 1 present Summary of Some climatic condition in DNP.

Fig. 1. Location of Dinder National Park

Tale 1. Summary of some climatic condition in Dinder National Park

Climatic Condition	Values
Absolute recorded maximum rainfall	967 mm / year
Absolute recorded minimum rainfall	450 mm
Log –term annual average rainfall	850 mm/ year
Rains month	July, August and September
Maximum average temperature	45 °C
Hottest month	April, May and June
Minimum average temperature	12 °C
Coolest month	January

2. The Importance of the Park:

The global significance of DNP arises from its geo-physical location. DNP lies along the transition ecotone between two floristic regions: the Ethiopian highland plateau and the arid Sahara Sudanian biomes. The park also lies along the boundary of two major faunal realms i.e. the Palearctic and Ethiopian realms. DNP is also situated along the north- south flyway of migratory birds. Thus the protection of the park is of global importance as it provides a refuge for large number of migratory and resident birds which live in the region or are permanent inhabitants of the park.

The national significance of DNP arises from its rich biodiversity (fauna and flora) which is not found elsewhere in northern part of the country. Locally its importance can be seen from, being a biosphere reserve within the UNESCO network since 1979, which is meant to integrate local communities in the conservation and sustainable use of biodiversity.

The significance of DNP as a watershed area for rivers Dinder and Rahad and its wetlands "Mayas" were the major reason behind the designation of the park as a RAMSAR Site in 2005. The resent archaeological discoveries in DNP could enhance its significance as a cultural Site. DNP has an indigenous tribe the ‘Gumuz’ which has been living in the park since 1912. Large numbers of immigrants have settled along the Rahad and Dinder Rivers outside the boundary of the park since 1970s. Most of these immigrants came from the famine-stricken areas in western Sudan and West African countries together with the droughts of 1980s (Mohamed, 1999 and Suliman, 1986).

3. Water Resources

The Rahad and Dinder rivers are the largest tributaries of the Blue Nile. They have nearly the same length, identical hydrology and comparable volumes of annual flows. River Rahad flows through the northern boundary of the Park, while the Dinder flows through the center of the Park (Fig. 2).

The catchments area of the Dinder River is around 16,000 km^2 and has annual discharge of about $3x10^9$ m^3. The channel traversing the Park ranges from 150 to 400 m in width and is 1-9 m in depth. The river starts surging in June, peaking around the middle of August each year. It ceases flowing in November. The sandy riverbed is left with numerous pools, some of which may retain water throughout the dry season.

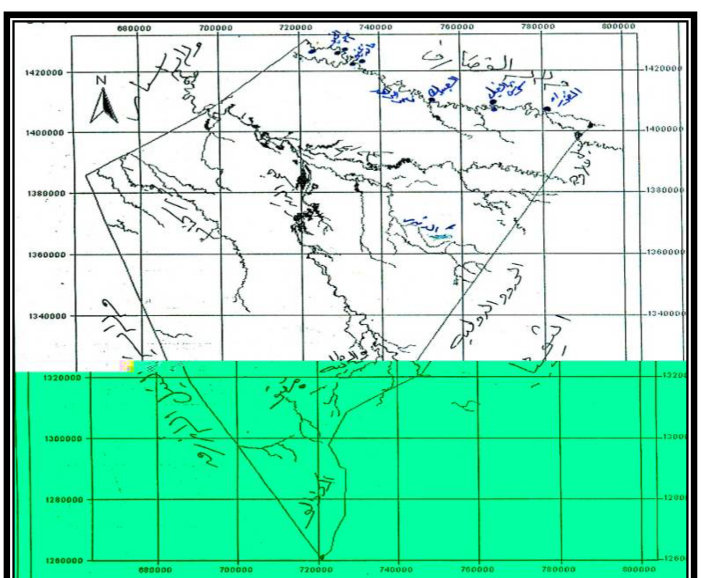

Fig. 2. Drainage System of Dinder National Park

4. Mayas

These are wetland meadows found along the flood plains of the rivers. They have been formed due the meandering character of the channel and nature of flow of its waters. They occupy low- lying basins, meander and oxbows. They are generally crescent with light and / or no clear banks.

The hydrology of the mayas is not very clear and more in-depth studies are required (Abdelhameed *et al.*, 1999). Mayas vary in areas from less than 200 m^2, to 4.5 km^2. Their use for grazing has been extensively studied by Eltom (1982) Abdalhameed (1983) Hashim (1987) and others. They have been, consequently classified as productive and non- productive habitats, based on their carrying capacities and water retention potential. The work of Abdalhameed *et al*., (1996 a and b), on the hydrology and drainage system of the Dinder River and tributaries forms a strong baseline to any further investigation. Ali (2001) has also studied the hydrology of the Park.

The Mayas receive their waters through direct rainfall, sheet flow and from Dinder river and tributary feeder channel, or from channels flowing through. A good indicator here is the occurrence of fish in years of high river flow. According to Abdalhameed *et al*, (1996a) the basic drainage system in the park is a tree-root like pattern (Fig. 2). The main drainage system is outlined as follows:

4.1. Khour Galegu: Khour Galegu is a major tributary of Dinder river. The system includes at least 40 Mayas, the largest of which is Ras Amir, 4.5 km^2 in area and 13 km northeast of the camp at Galegu. It rarely dried up before 1970, and since then, it became less perennial, drying up every few years. The second large maya is Farsh Alnaam, 22 km east of the series of mayas known as Godaha, mostly dry after the drought of 1980(s). The Godaha are a chain of eleven small mayas connected to the adjacent Khour Galegu with well defined channels. In the upstream of Khour Galegu the mayas are less known due to inaccessibility of the terrain.

4.2. Khour Masaweek: The Khour is also a large tributary of the Dinder river. The prominent mayas in the drainage system total 11 in number. Sambroug is the largest, with an area of around 2.3 km^2. The Khour flows through the crescent shaped wetland.

4.3. The Eastern bank of the Dinder River: At least 12 mayas are found .The most conspicuous are Ein Eshams (about 1.8 km^2), Mayat Simseer and Alabyad.

4.4.The Western bank of Dinder river; there are at least 13 large mayas. The most conscious include Gererisa (about 2 Km^2), Simaya (which is located 25 Km south Galegu Camp) and Beit Alohash.

4.5. Other drainage system: There are numerous other less known mayas along the various tributaries of the Dinder River essentially Khour Alatshan, Khour Elatesh and Khour Kennana.

A number of pools remain on sandy bed of the Dinder River, after it ceases to flow. Examples of these are Birkat el tumaseh, Elgezira Umurrug, Elhunna elazerag, Elzommati and Eltabia. In 2005 a survey from Suneit to Alabyiad (about 55 km), revealed the presence of more than 40 water pools varying in size. These pools are not well studied in relation to their dynamics and water holding capacity. Some get silted up like Dabkara while new ones are probably created. The pools are rich in fish and water birds (Fig. 3). Occasionally small crocodiles and Nile Monitor are found.

The pools of Rahad river are intensively used by the communities on the eastern bank. Water is used for irrigation of crops and domestic purposes.

Fig. 3. Aquatic birds in a Maya in the Dinder National Park.

5. Ecosystem of the Park

5.1. Riverine ecosystem: The riverine ecosystem occurs on the sandy banks of Dinder and Rahad Rivers. The forest is multilayered vegetation dominated by *Ficus sycomorus*, *Acacia sieberina*, *Stererospermum kunthianum*, *Tamarindus indica*, *Combretum hartmannianum*, *Ziziphus spina chrisrti* , *Gardina lutea* and *Pilostigma reticulatum*. The main grasses include *Beckerospsis unisetz*, *Eragrostis tremula* and *Sorghum sudanica* with different species of forbs and climbers forming the ground floor layer.

The composition of the riverine forest changes gradually as one goes to the southwards. The southern extreme of this ecosystem is dominated by *Anogeissus leiocorpus* and *C. hartmannianum*, *Terminalia browni*, *Boswellia payriffera* and *Adonsonia digitara*. Grasses such as *Andropogon gayanus*, *Hyperrhenia ruffa*. and *Setaria incrassate*are dominan Creepers such as *Caparis tomentosa*, and climbers such as *Cissus quadrangularis*, epiphytes like *Loranthus* sp, lichens and mosses.

5.2. The woodland ecosystem: which is largest part of the Park, this ecosystem is dominated by *Acacia seyal, Balanaties aegyptica* and *C. harttannianum* and grasses like *Sorghum sudanensis*.

5.3. The mayas ecosystem: The bed of Ras Amir is almost devoid of vegetation, except for a few herbs and scattered shrubs. The productive mayas are those which retain water throughout the dry season. The productive mayas vegetation includes: *Nymphia* spp, *Brachinochola stagnina*, *Cyndon dactylon*, *Kylliga* sp., *Brcharia* sp. and *Ipomea*

aquayica. The standing crop of green forage and fish supports a large number of ungulates and birds throughout the dry season.
The non productive mayas are those which do not retain their water throughout the dry season. The dryness of the mayas could be caused by silt or by the river dynamics. Dry mayas are usually dominated with *Sorghum sudanensis* and *Hibhscus* spp. Newly reported invading plants such as "elsorrib" *Chamaecrista nigrieeans* and *Cassia* spp which are invading Gererisa, Semsir and Alsimaia. Other degraded maya and classified as less productive include Beit Alwash, Farsh elnaam and el Godaha.

6. Mammals, birds, fish and reptile of the Mayas

The maya ecosystem is the most important habitat for mammals and birds of the Park during the dry season. The "productive" Mayas usually provide animals with grazing, water and cover. Mammals that depend on the mayas during the dry season include the following: Bohor reedbuck (*Redunca redunca*), waterbuck (*Kobus ellipsiprymus*), Oribi (*Ourebia ourebia*), African buffalo (*Syncerus caffer caffer*) Baboon (*Papio anubis*), Warthog (*Phacochoerus aethiopicus*), roan antelope (*Hippotragus equines*), Lion (*Panthera leo*, Fig. 4), striped hyaena (*Hyaena hyaena*) and others.

Fig. 4. A lion (*Panthera leo*) in a maya at Dinder National Park

Birds that using the maya ecosystem includes: the ostrich (*Struthio camelus*); several water birds such as Pink-backed Pelican (*Peleconuse rufescens*), Open-billed Stork (*Anastomus lameligerus*), Wooly-necked Stork (*Ciconia episcopus*), Abdim"s Stork (*Ciconia abdimii*), Yellow-billed stork (*Mycteria ibis*), ducks and geese such as Fulvous Whistling Duck (*Dendrocygna bicolor*), White-faced Whistling Duck (*Dendrocygna viduata*), Egyptian goose (*Alpochen aegyptiacus*), Spur-winged Goose (*Plectropterus gambensis*) and Knob-billed Duck (*Sarkidoris melanotis*); Herons, bitterns and egret (*Egretta garzetta*): shore birds such as Jacana (*Actopilornis africanus*), Black –winged

Stilt (*Himantopus himantopus*); birds of prey such as Hooded Vulture (*Neophron monachus*), Long-crested Eagle (*Lobbactus occiptalis*), Fish Eagle (*Haliaaeetus vocifer*) and black kite (*Mlivus nigrans*). The Nile crocodile (*Crocodilus niloticus*) monitor lizard (*Varanus niloticus*), African python (*Python sebae*) and many other species of snakes represent the reptile species that occur in mayas of the Park.

Mayas Simser, Samaaya, Gereisa and Ras Amir were found to have good diversity of fish and good productivity (Abdelmoneium Khalid, 2003 personal communication). Out of 32 species of fish species identified in mayas of the Park, the most important species are “garmut” (*Clarias lazera*) "nook" (*Heterotis niloticus*), “gurgur” (*Snodontis* spp.) and “bulti” (*Oreochromis niloticus*).

7. Management of the Mayas in DNP

Emphasis of the Park authority is on law enforcement activities with limited intervention on ecosystem management. Combating poaching, control of livestock trespassing and grazing in the mayas, control of illegal fishing are the main law enforcement activities.

All of DNP is subject to frequent and sometime intense burning. Fire starts as early as mid- September and its usually very damaging late in dry season. Mayas are subjected to fires in dry years. Fire can be used as a management tool at the time and in place needed to achieve Park’s objectives. The Park authority did not adopt specific fire management policy.

Since the 1970s the park experienced periods of serious drought where active intervention has been needed to provide drinking water for the animal in the mayas. Two deep wells were drilled in Ras Amir (Fig. 5) and Gererisa maya and water is pumped from these wells during drought year and they are successfully maintained by the Park authority.

Fig. 5. Maya Ras Amir (Dinder National Park)

The Institute of Environmental Studies (IES) of University of Khartoum early in the 1980s did an intervention in Simmaia Maya opening a feeder channel to the Maya. The maya which had been dry and unproductive had been revitalized and its water retention capacity had been increased greatly, fish productivity enhanced and mammals and birds using maya had been increased. This intervention sustained productivity for almost 20 years. Other recent interventions were made by DNPP in 2002 – 2004 where two mayas Abdel Gani and Simmaia had been excavated in the middle of the mayas and silts was removed away to increase the retention capacities. In addition to opening of two feeders at Beit Alwoash and Gerereisa, another intervention by DNPP was the installation of about 7 pools in selected Mayas for flood measurement and monitoring.

8. Proposed management of the mayas

The Management Plan for DNP (2005) included emphasis on mayas and pools in the Park. Mayas and pools are critical areas for wildlife management. The link between the biomass of wild ungulates and birds which are supported by mayas and degradation and/or siltation of the mayas, and decreased water retention capacity during the dry season could be established. The Management Plan included quick actions to be taken to revitalize the Maya ecosystem. Excavation of the beds of mayas was proposed for Abdel Gani, Simmaya, Gererisa, Beit Alwhash, Ein Eshames, Mayat Musa, Heneifa, RAS amir, Abyad, Semsir and Sambrog . Excavation will be done after conducting topographic survey of the mayas. Also it is suggested that excavation of the mayas will be carried out in patterns of squares. The depth will be deepest at the centre and will be reduced gradually towards the periphery so as not to impede movement of animals.

Opening blocked feeders of maya should be carried out after conducting hydrological surveys and contour mapping .Also detailed hydrological studies and monitoring of important mayas should be carried out.

8.a. Removal of invaders: The presence of exotic or alien species in a protected area is generally contrary to the management objectives of such areas. Dominant invaders are 'elsorrib' *Cassia nigrieans* and *Chorchorus olitorious*. Methodology for removal of invaders should be decided based on nature and growth habits of invader plants and use of chemicals is to be avoided.

8.b. Fire management: The bottom of feeders of the mayas sometimes carry dense cover of untouched perennial grasses . Prescribed burning every four years is recommended to prevent sedimentation of the feeder. Attention should be paid against burning on the slopes and banks of the seasonal water channels.

8.c. The fresh water habitats: Fresh water habitats should be conserved and protected to preserve its fish species and other aquatic fauna and flora. All form of fishing activities should be banned on the breeding grounds and natural nursery areas formed by the floating reeds and macrophytes. Fishing activities can be practiced in pools and mayas which dry up totally before the next flood season, using only traditional gear and not disturbing animals or birds using the site. Fishing is recommended to be between December to March.

8.d. livestock grazing: Overgrazing is a serious threat to many important mayas in the Park. It makes the ground of mayas more compact, introducing exotic species which compete with palatable perennial grasses beside transmission of diseases between wild animals and livestock, therefore these mayas should be protected from overgrazing.

9. Conclusions

The mayas ecosystem is a very important component of Dinder National Park. It constitutes the most significance part of the dry season habitat for most of the animals in the park. Management of the mayas ecosystem requires good understanding of the hydrology of the park. It is important to keep a good monitoring program of the Maya hydrology to precede any intervention.

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Chapter 3: Biodiversity of Aquatic Non-vascular Plants with Special Emphasis on the Phytoplankton.

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1. Introduction

Non-vascular plants include: algae, bryophytes, and lichens. In general, the study of bryophytes and lichens in the Sudan is sadly neglected. Unfortunately no published information is available on biodiversity of bryophytes and lichens within the Nile catchment area in the Sudan. This lack of information is one of the serious gaps in our knowledge which needs to be filled.

Freshwater algae (Fig. 1a and b) received more attention than the other non-vascular plants. Algae are small, mostly microscopic, aquatic microphytes that contribute considerably to primary production within the Nile ecosystem. Together with organic matter added by riparian vegetation, algae constitute the bottom of the aquatic food pyramid that culminates in the production of such consumers as waterfowl or fish.

Fig. 1a

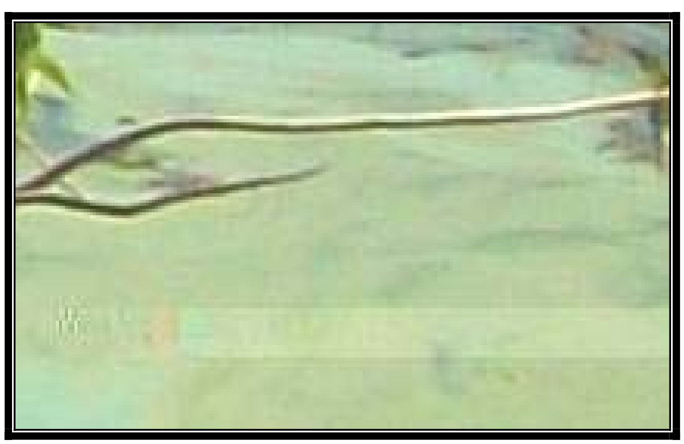

Fig. 1b

Fig. 1. An algal bloom at Al Ragaba, 10km south of Roseries Dam (Januaray, 2009, Source; Prof. Zuheir N. Mahmoud)

In aquatic ecosystems there two types of algal communities: planktonic algae (phytoplankton) which live suspended in water and benthic algae which attach themselves to the bottom of the river. All research workers focused entirely on the phytoplankton of the White Nile and Blue Nile. Benthic algae of the Nile and soil algae of adjacent wetlands and lakes were completely neglected, thus presenting another gap in our knowledge which needs to be filled. This paper is an account pertaining only to the biodiversity of the phytoplankton encountered in the White Nile.

For the purpose of this paper the Nile System within the Sudan is divided into the three major rivers traversing the Sudan plain, namely the Blue Nile, the White Nile and the Main Nile. The latter, receiving only one tributary, the Atbara River coming from the Ethiopian plateau, finds its way northwards to Egypt. The White Nile originates from the equatorial lakes on the lake plateau and is joined by the Sobat which originate from the Ethiopian plateau and by the Bahr Alghazal flowing eastwards from the Nile-Congo watershed. The Blue Nile and its two ephemeral streams the Dinder and the Rahad Rivers also originate from the Ethiopian plateau.

2. Research on biodiversity of the phytoplankton of the White Nile.

In reviewing research on phytoplankton biodiversity, the White Nile from Sudanese–Ugandan boarder to Khartoum is divided arbitrarily into five zones so as to make it easier for the reader to build a clear picture and see differences between the five zones. Also this approach magnifies knowledge gaps in phytoplankton research in the White Nile. These zones are shown in Table 1.

Zone I which extends for about 100 km of free river flow along Bahr Algebel from the Sudanese-Ugandan border to Town of Bor is not studied and no information is available about the biodiversity of algae along this stretch of the White Nile.

Zone II is comprised of two main tributaries Bahr Algebel and Bahr Alzaraf Rivers which twine through the Sudd swamps for 540 km. Many ephemeral streams, swamps, and lakes are connected to the two rivers. The Sudd region algae received very little attention. The few attempts to deal with the limnology of the Sudd were confined to physical and chemical aspects of the river water (Talling, 1957) and scattered observations that the two rivers carry rudimentary impure plankton and rich detritus suspension and that phytoplankton to be present in low densities near or below the limits of quantitative estimation. (Rzoska et al., 1955; Sinada, unpublished).

Table 1. White Nile zones within the Sudan Plain

Zone	Description	Comments
I	From Sudanese-Ugandan border to Bor (Bahr Algebel River)	About 100 km zone of free river flow
II	Sudd region: from Bor to Lake No/Malakal (Bahr Algebel and Bahr Alzaraf River)	The two main tributaries twine through the Sudd swamps for 540 km
III	From Malakal to Gebel Aulia reservoir	Zone of free river flow not affected by the backwater of Gebel Aulia dam

IV	The Gebel Aulia reservoir	Backwater effect extending 260 km upstream
V	From Gebel Aulia dam to Khartoum.	45 km Zone of free river flow to confluence with the Blue Nile

However in the Sudd swamps, adjacent bodies of standing water are frequent and often bear rich planktonic populations (e.g. Prowse 1954; Talling 1957). These will contribute some cells to the main river. A more remarkable and completely different development of phytoplankton exists in one such water, Lake Ambadi, on a tributary system (Bahr Alghazal) with distinctive water chemistry. There Gronblad et a.l (1958) found several species like Dinobryon sertularia, Botrycoccus braunii, Asterococcus limneticus rarely or never recorded elsewhere from Sudanese Nile, whereas the more common species of the main river and lagoon were not seen. Still more distinctive of Lake Ambadi, and adjacent parts of the Bahr Alghazal, is the exceptional diversity of desmids, some not recorded elsewhere (Gronblad et al. 1958, Gronblad 1962). During a single visit to Lake Ambadi in an impressive successful attempt they identified 205 species and varieties of planktonic desmids including 21 new species and 48 new varieties and forms and of particular interest was the discovery of a new asymmetrical type of Micrasterias represented by M. incredibilis and M. sudanensis .Most probably most of these new records of desmids are rare if not endemic.

Zone III is a Zone of free river flow From Malakal Town to tail of Gebel Aulia reservoir not affected by the backwater of Gebel Aulia dam. Virtually no information on planktonic algae of this stretch of the White Nile is available except for limited observations by Prowse and Talling (1958).

Zone IV is Gebel Aulia reservoir with its backwater effect extending 260 km upstream the dam. The phytoplankton of the reservoir received more attention than upstream zones (Prowse and Talling, 1958; Brook and Rzoska, 1954; Abdel Karim and Saeed, 1978).

Zone V extends for 45 km From Gebel Aulia dam to the confluence with the Blue Nile at Khartoum. This is the most studied zone of the White Nile. The diversity of the phytoplankton of this zone is well documented (Brook, 1954; Rzoska et al., 1955, Prowse and Talling, 1958; Sinada, 1972; Sinada and Abdel Karim, 1984; Yousif, 2004; Sinada, unpublished data, 2000-2006).

3. Biodiversity of the phytoplankton of the White Nile

In Table 2 the total numbers of planktonic algae encountered in the White Nile at Khartoum during different and widely separated periods of times are presented.

As a result of long years of systematic investigations, much data concerning the Blue Nile and White Nile phytoplankton in Khartoum vicinity is available.The phytoplankton of both Niles consists mainly of the Bacillariophyceae, Chlorophyceae and Cyanophyceae.

This diversity is not uniform at different times. As shown in Table 2, during 2000-2001, a total of 144 species and varieties, belonging to 79 genera of 5 classes were reported in the White Nile at Khartoum. On the other hand, studies conducted during 1968-1970 revealed that the level of phytoplankton diversity is lowest with only 72 species and varieties while earlier, during 1949-1952, about 114 species and varieties were reported.

Table 2. Total numbers of planktonic algae encountered in the White Nile at Khartoum during different and widely separated times

Taxa (Classes and Orders)	Abdelrahman (2004) (2000-2001)	Sinada (1972) (1968-1970)	Brook (1954) (1949-1952)
1.Chlorophyceae	73	38	72
Volvocales	4	2	9
Chlorococales	48	26	34
Oedogoniales	1	0	0
Chaetophorales	3	0	0
Zygnematales	17	20	26
2.Cyanophyceae	25	15	22
Chroococcales	10	3	8
Oscillatoriales	6	4	8
Nostocales	9	8	6
3.Bacillariophyceae	43	29	18
Centrales	9	6	8
Pennales	34	23	10
4.Euglenophyceae	2	0	2
Euglenales	2	0	2
5.Dinophyceae	1	0	0
Peridinales	1	0	0
Total	144	72	114

4. Research on biodiversity of the phytoplankton of the Blue Nile

Similarly the Blue Nile may be divided arbitrarily into six zones (Table 3) from Sudanese–Ethiopian boarder to its confluence with the White Nile at Khartoum. This approach may highlight gaps in our knowledge of the phytoplankton biodiversity of the Blue Nile which need to be filled.

Table 3. Blue Nile zones within the Sudan Plain

Zone	Location	Comments
I	Sudanese-Ethiopian border to tail of Roseires reservoir	About 100 km zone of free river flow not affected by the backwater of Roseires dam

II	The Roseires reservoir	Backwater effect extends about 100 km upstream
III	Roseires dam to Sennar reservoir	Zone of free river flow not affected by the backwater of Sennar dam
IV	The Sennar reservoir	Backwater effect extending 140 km upstream
V	**Sennar dam to some few kms south of Khartoum.**	**Zone of free river flow receiving the Dinder and the Rahad seasonal tributaries:**
VI	Vicinity of Khartoum	5 km river length east of confluence with the White Nile

Zones I-IV received some attention before and after the construction of Roseires dam documenting the effect of Roseires dam on the biodiversity of planktonic algae. All credit goes to high quality limnological works which have been carried out by members and collaborators of the Hydrobiological Research Unit and which has contributed considerably to our knowledge of the biology of the Nile within the Sudan particularly the biodiversity of phytoplankton of the Blue Nile.

The Hydrobiological Research Unit of the University of Khartoum launched in 1963, three years before the completion of Roseires dam a long-term study of the whole 740 length of the Blue Nile within the Sudan to determine the impact of Roseires dam on the biological conditions of the river. A survey was carried out on conditions before and after the dam was put into use. The above-mentioned valuable studies carried out by Brook (1954), Rzoska et al. (1955), Talling & Rzoska (1967) and Hammerton (1970 a, b; 1971a) have provided much of the baseline data for comparison with conditions in the newly formed reservoir and in the river after the filling of the reservoir.

Hammerton (1970 a, b; 1971 a,b,c,d; 1972a,b) in his longitudinal surveys of the Blue Nile along Zones I-V before and after the construction of Roseires dam documented the impact of Roseires Dam on the biodiversity of planktonic algae. Hammerton (1970 a, b; 1971 a) in three different surveys carried out during February 1964, February 1965 and February 1966 found an extremely sparse plankton population in 400 km section of the river upstream of Sennar reservoir.

Zone VI in the vicinity of Khartoum similar to the White Nile is well studied. The biodiversity of Planktonic algae is near Khartoum is well documented (Brook, 1954; Rzoska et al, 1955, Talling and Rzoska, 1967; Sinada, 1972; Sinada and Abdel Karim, 1984; Ali; 1999; Abdel Rahman, 2004; Sinada, unpublished data, 2000-2006).

5. Biodiversity of the phytoplankton of the Blue Nile

In Table 4 the total numbers of planktonic algae encountered in the Blue Nile at Khartoum during different and widely separated periods of times are presented.

Long years of systematic investigations in the Blue Nile and White Nile phytoplankton in Khartoum vicinity led to accumulation of much data. Similar to conditions in the White Nile, the phytoplankton of the Blue Nile at Khartoum consists mainly of the Bacillariophyceae, Chlorophyceae and Cyanophyceae.

This diversity is not uniform at different times. As shown in Table 4, during 2000-2001, a total of 134 species and varieties, belonging to more than 80 genera of 5 classes were reported in the White Nile at Khartoum. On the other hand, studies conducted during 1968-1970 revealed that the level of phytoplankton diversity is highest with more than 140 species and varieties while earlier, during 1949-1952, the level of phytoplankton diversity is lowest with only about 98 species and varieties being reported.

Table 4. Total numbers of planktonic algae encountered in the Blue Nile at Khartoum during different and widely separated times

Taxa (Classes and Orders)	Yousif (2004) (2000-2001)	Sinada (1972) (1968-1970)	Brook (1954) (1949-1952)
1. Chlorophyceae	63	67	65
Volvocales	3	8	11
Chlorococales	51	40	43
Oedogoniales	0	0	0
Chaetophorales	0	0	0
Zygnematales	9	19	11
2. Cyanophyceae	19	17	20
Chroococcales	12	5	8
Oscillatoriales	3	6	4
Nostocales	4	6	8
3. Bacillariophyceae	38	46	10
Centrales	8	6	5
Pennales	30	40	5
4. Euglenophyceae	11	10	3
Euglenales	11	10	3
5. Dinophyceae	3	2	0
Peridinales	3	2	0
Total	134	142	98

6. Gaps in knowledge of phytoplankton biodiversity in the Nile sub-basins

Research on planktonic algae of the Nile within the Sudan began in 19th century and still continues. Researchers presented adequate information on the biodiversity of planktonic algae in the vicinity of Khartoum. Although the research has been carried out at various stretches of the Nile downstream Khartoum, most of the work was confined in

the vicinity of Khartoum due to logistic reasons. The study of most fortunate stretches of the Nile has been performed only once. This creates difficulty in making precise evaluations of the biodiversity and changes that might have taken place over time, if any. Many regions are not sufficiently studied like upper White Nile and its tributaries in the Sudd region and Bahr Alghazal and Lake Gebel Aulia. Other water basins of the country have not yet been studied like Sobat River, and Atbara River. The Main Nile from Khartoum to Sudanese-Egyptian border is hardly studied. A few samples collected by Rzóska (1958) and Hammerton (1970; 1972b) between Dongola region, and Wadi Halfa. The phytoplankton biodiversity of a number of regions in the Blue Nile are still not fully investigated like Roseires reservoir, Sennar reservoir, and Blue Nile stretch between Sennar and Khartoum. Dinder and Rahad Rivers are not studied yet. It is not unreasonable to assume that the algae flora of Sudan is poorly studied and all the sub-basins mentioned in this paper need to be thoroughly studied to lay the baseline information on the biodiversity of the phytoplankton of the Nile within the Sudan.
There are many lakes and wetlands connected to the White Nile. No information is available concerning the algal flora of lakes and wetlands along the White Nile in South of Sudan. Indeed, the Sudd swamps, the Bahr Alghazal swamps and the Machar marshes, three of the largest tropical natural wetlands in Africa are poorly studied. Much research is to be done to gather information and fill gaps in the biodiversity of vascular and non-vascular plants in these important wetlands. To start with a series of systematic checklists may be made.

7. Threats to the phytoplankton biodiversity in the Nile

Fortunately Dam construction across the Blue Nile and White Nile has had a positive impact on diversity which increased substantially after the construction of the dams.

Over the period 1950-2000, the biodiversity of the Blue Nile and White Nile phytoplankton at Khartoum has undergone considerable changes. The change in late sixties in the Blue Nile may be attributed to the construction of Roseires dam in the Blue Nile and the chemical control of the invasive water hyacinth in the White Nile. The change which took place in the last two decades may be attributed to eutrophication due to the intensive use of fertilizers in agricultural land within the catchment area of the Blue Nile and White Nile. The increase in phytoplankton biomass is associated with increase in the concentration of dissolved nitrate and phosphate. Eutrophication in the Blue Nile results in blooms, some of which have adverse effects as that which appeared in May 2003 (Sinada, unpublished).

Considerable and fast changes and therefore loss of biodiversity in phytoplankton of the White Nile and Blue Nile particularly in lakes and wetlands in the Sudd region in South of Sudan may take place in the future if the right measures are not taken to prevent loss of Biodiversity. Causes of the adverse changes may be enumerated in the following anthropogenic factors:

7.1. Eutrophication from agricultural land in the catchment area where agrochemicals are expected to reach the Nile, particularly the Blue Nile, from diffuse sources during wet seasons.

7.2. Pollution caused by industrialization where many factories may discharge their untreated waste waters directly into the Blue Nile and White Nile.

7.3. Rapid urbanization and increase in population and the need to dispose of raw sewage directly into the White Nile and Blue Nile.

7.4. The completion of Jonglei canal is expected to exert a negative impact on the biodiversity of aquatic plants including phytoplankton as a result of draining some interesting lakes and wetlands. Interesting algal flora may disappear.

7.5. Oil pollution due to oil development and exploration in the heart of the Sudd region will have adverse impact on the diversity of algae in the White Nile if high international standards are not adopted by oil companies.

8. Recommendations

In order to protect the biodiversity of algae in the Nile system within the Sudan the following recommendations are suggested:

8.1. Fill gaps in our knowledge by studying the neglected groups of non-vascular plants and neglected tributaries, sub-basins, and stretches of the Main Nile, Blue Nile, and White Nile.

8.2. Minimize the amounts of fertilizers and pesticides reaching the Blue Nile and White Nile by adopting new good agricultural practices that will reduce the use of pesticides and fertilizers and be more environmentally friendly.

8.3. Enforce regulations to prevent industrial waste and sewage effluents from being discharged into the Nile above permissible levels.

8.4. Abandon the construction of Jonglei canal and compensate the share of the Sudanof the 2 km^3 water from other sources.

8.5. Force the oil companies developing Blocks within the Sudd region to adopt high international standards of pollution prevention. Produced formation water must not be discharged into the Sudd swamps without treating the waste water to reduce the amounts of hydrocarbons, heavy metals and other contaminants to permissible levels.

8.6. Of great interest are the tropical swamps and the many lakes and wetlands connected to the White Nile that may sadly be adversely affected by pollution from oil development. Such lakes may have unique features when compared to other groups of lakes and may be described or assessed as endangered lakes. Some have been shown to contain diverse and abundant species of freshwater planktonic desmids. New protected areas are to be established in order to stop any process of deterioration. Declare Lake Ambadi a protected water habitat which contain diverse and abundant and probably endangered desmid flora.

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