Aquatic Plants of the Sudan

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Abstract The hydrophytes of the Sudan range from small floating plants to the tall reeds of the Sudd. They inhabit a diversity of habitats, and show remarkable vertical and longitudinal zonation, phyletism, growth forms and ecology. Ninety-five species belonging to 33 families are on record. One taxon (*Suddia*) is endemic. Their status reveals a disheartening situation. Negligence is reflected in meager studies, no attempts to utilize and no policy to conserve.

To conserve the diversity of the hydrophytes of the Sudan, a delicate balance between utilization, conservation and control is required. The fact that the Sudd has recently been declared a Ramsar site raises hopes that these objectives may be reached in a near future.

1 Introduction

The aquatic vegetation of the Sudan has not been well studied. This is reflected in meager knowledge, almost no attempts to utilize these plants, and a complete absence of a policy to conserve them. This chapter endeavours to highlight the diversity in Sudanese aquatic plants in habitats, distribution, phyletism, growth forms and ecological niches. The term "aquatic plants" is used to designate those macrophytes that are truly aquatic, including the bank trees but excluding the microphytes (algae).

2 Aquatic Habitats of the Sudan

2.1 Running Waters

The main Nile runs for more than 3,000 km within the confines of Sudan. The Blue Nile, the 2,000 km of the tributaries of the White Nile, and the seasonal rivers Atbara, Dinder and Rahad together add up to over 6,000 km (Beshir & El-Moghrabi,

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H.J. Dumont (ed.), *The Nile: Origin, Environments, Limnology and Human Use*,

1980). All four main rivers (White Nile, Sobat, Blue Nile and Atbara) in addition to many seasonal khors, discharge into the Main Nile within Sudan. The five sub-basins of the Nile are all represented within the Sudan (Fig. 1). As described by Ali (1990), the Sudan Nile is a mosaic of contrasting combinations: long and short, fast and slow, permanent and seasonal, silty and clear, infested and weed-free, dammed and free-flowing. One of its salient characteristics is the swamps of its upper reaches, which include the famous "Sudd", the most extensive wetland in the world (Thompson, 1985; Green & El-Moghraby, 2009) (Fig. 3). The Sudd has witnessed remarkable events during the 1960s–1980s, caused by unprecedented rise in the level of Lake Victoria between 1961 and 1964 (Beadle, 1974), which nearly doubled the area of swamp (El-Moghraby & El Sammani, 1985; Howell et al., 1988) and the low discharge of the Blue Nile in the early 1980s. These were natural phenomena, while the advent of the water hyacinth (*Eichhornia crassipes*) in 1958 (Gay, 1958) and its proliferation in the White Nile, the construction of Roseires and the Aswan high Dams were anthropogenic events. Both had equally profound impacts (Ali, 1990).

In addition to the "Sudd", the Machar and the Bahr al Ghazal Swamps should be mentioned (Fig. 2). The first is a triangle north of the River Sobat and east of the White Nile taking its name from Khor Machar. The swamps are fed by local precipitation and by numerous small torrents rising in the Ethiopian foothills over c. 200 km from south to north. The area also receives spill water through various channels from the Sobat (JIT, 1954). Though there are at times measurable discharges to the White Nile from Khors Adar and Wol, this amount is small. The area of seasonally flooded marchland and swamp is estimated at c. 6,500 km^2 (Howell et al., 1988).

The other wetland, the Bahr al Ghazal swamp, is fed by local precipitation and rivers descending from near the Sudan-Congo-Chad divide. The combined annual discharge of the main Bahr el Ghazal tributaries is ca 13.5 km^2. Most of this water eventually evaporates or transpires in seasonally inundated floodplains and permanent swamps. It never reaches the Nile.

2.2 Natural Lakes

Among freshwater lakes in western Sudan, Lake Kundi lies in southern Darfur, close to the seasonal Bahr el Arab. Lake Keilak is situated in South Kordofan, about 200 km north of the junction of Bahr el Arab and Bahr el Ghazal (Fig. 1). The drainage system of the two lakes, their bathymetric features, their physical–chemical properties and their biota are discussed by Green et al. (1984). Lake Kundi has a vegetation dominated by *Ceratophyllum demersum* and *Nymphaea lotus*, while Lake Keilak is rich in *Ceratophyllum demersum*, *Najas pectinata and Nymphaea lotus*. Beside these, there are two crater lakes in Darfur: the Dariba lakes in the volcanic caldera of Jebel Marra (Green et al., 1979) and the Malha salt lake in the Meidob Hills.

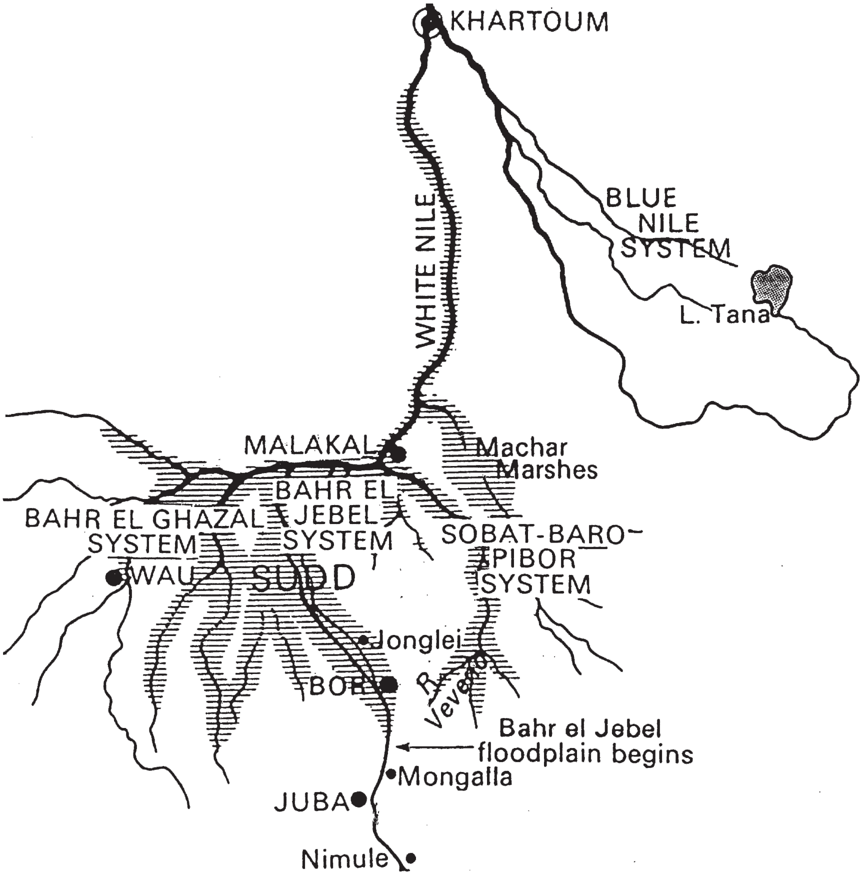

Fig. 1 The part of the Nile basin in Sudan and adjacent countries

2.3 Man-Made Lakes

The construction of a number of dams has resulted in the creation of large impoundments. These include Sennar and Roseires on the Blue Nile, Khashm el Girba on the River Atbara and Lake Nubia on the main Nile (Fig. 1). A new large lake has already formed by the impoundment of Merowe Reservoir in 2008.

3 The Diversity of Aquatic Plants

Although Dandy (1937) reported seven *Potamogeton* species, no study was dedicated to aquatic plants before 1948, although aquatic plants were mentioned sporadically by travelers and bird watchers. Paradoxically, the “Sudd”, considered as a

Fig. 2 (**a**) and (**b**) Two typical aerial views of the Sudd, with the Bahr El Jebel meandering through several swampy Lakes. The reeds *Typha*, Papyrus and *Phragmites* occupy the wetlands. The big lake is inhabited by floating, submerged and floating-leaved hydrophytes. In the foreground of Fig. 3b, woody trees occupy the relatively higher ground (*see Color Plates)*

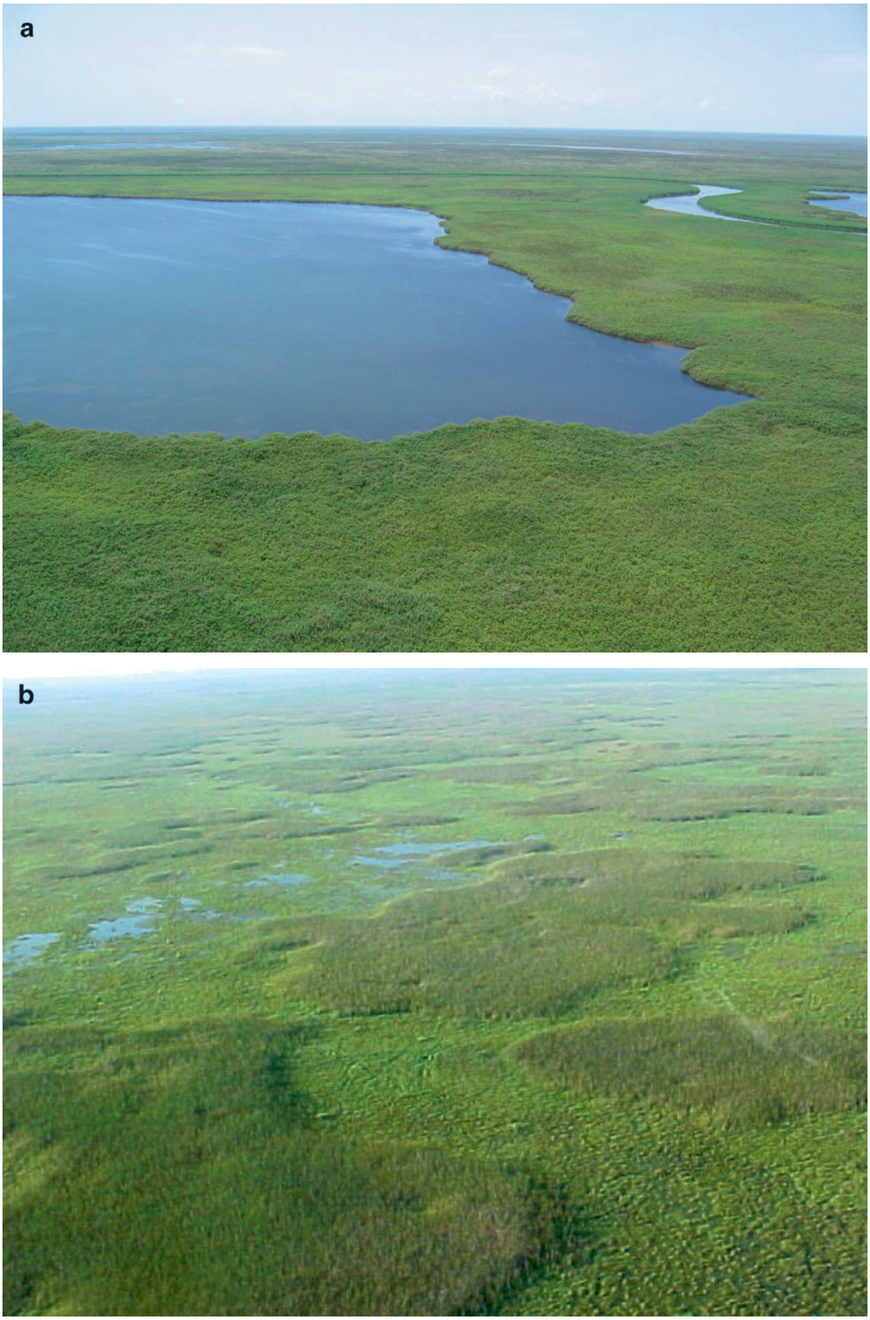

Fig. 3 (**a**) and (**b**) Vast swamps in the Sudd region occupied by *Typha domingensis* (*dark patches*) and *Cyperus papyrus* (*lighter green patches*). (**a**) Shows a large Sudd lake with the Bahr El Jebel in the background (*see Color Plates)*

political and a geographical blockage, drew the attention of scientists to the aquatic plants that constituted this natural barrier (Migahid, 1947, 1948; Dirar, 1951; Talling, 1957). The seminal paper by Migahid (1948) was the only in-depth attempt to describe its vegetation, even though interest in the Sudd vegetation was also spurred by plans to utilize the water lost in the swamps (Equatorial Investigation Team, Jonglei Investigation Team, 1954).

Attention to aquatic plants in Central Sudan was stimulated by problems with aquatic weeds in the Gezira irrigation scheme. Weeds started to grow few years after gravity irrigation started to operate and a rapid build-up took place (Andrews, 1945). The minor canals of the agricultural schemes provided excellent conditions for weed growth because of their design and sluggish flow (Beshir, 1978). As soon as a policy of intensification and diversification of cropping was adopted, aquatic plants became a serious problem (Hamdoun & Desougi, 1979). The work of Andrews (1945) was solely dedicated to aquatic macrophytes. Their taxonomy, morphology and distribution were dealt with in Andrews' three volumes on the flowering plants of Sudan (1950, 1952 and 1956).

The appearance of *Eichhornia crassipes* in the Nile in Sudan in 1958 was another landmark. By its adverse impact on evapotranspiration rates, navigation, irrigation pumps, water supply, and fisheries, the water hyacinth engendered research into aquatic weeds in general.

4 Habitat Diversity

Aquatic plants occupy all habitats described earlier. The geographical zonation in the distribution and diversity of aquatic plants follows a N-S gradient, linked with the southward increase in rain intensity and duration. The diversity is in the density of plants as well as in their types. The diversity of aquatic vegetation is also a reflection of the different aquatic habitats and their water characteristics. Thus, the vegetation of crater lakes is distinct from that in fresh waters. Only salt-tolerant *Scirpus* grow in the vicinity of some springs that feed the hypersaline Malha lake, Meidob Crater (pers. obs., 1985), but *Ceratophyllum demersum* and *Nymphaea lotus* abound in Lake Kundi and *Ceratophyllum demersum*, *Nymphaea lotus*, *N. coerulea* and *Najas pectinata* in Lake Keilak (Green et al., 1984). Within freshwater, plants in the main river axis are different from those in natural and man-made lakes. In the swampy region of the southern Sudan, aquatic macrophytes exhibit a horizontal zonation from the main river to the higher land (Fig. 4).

5 Phyletic Diversity

The aquatic plants of the Sudan belong to Charophyta (macro-algae), (Pteridophyta, Gymnosperms, and Angiosperms) (Table 1). The only wetland gymnosperm in Africa is *Podocarpus* (Denny, 1985), of which Andrews (1950) cited two species in

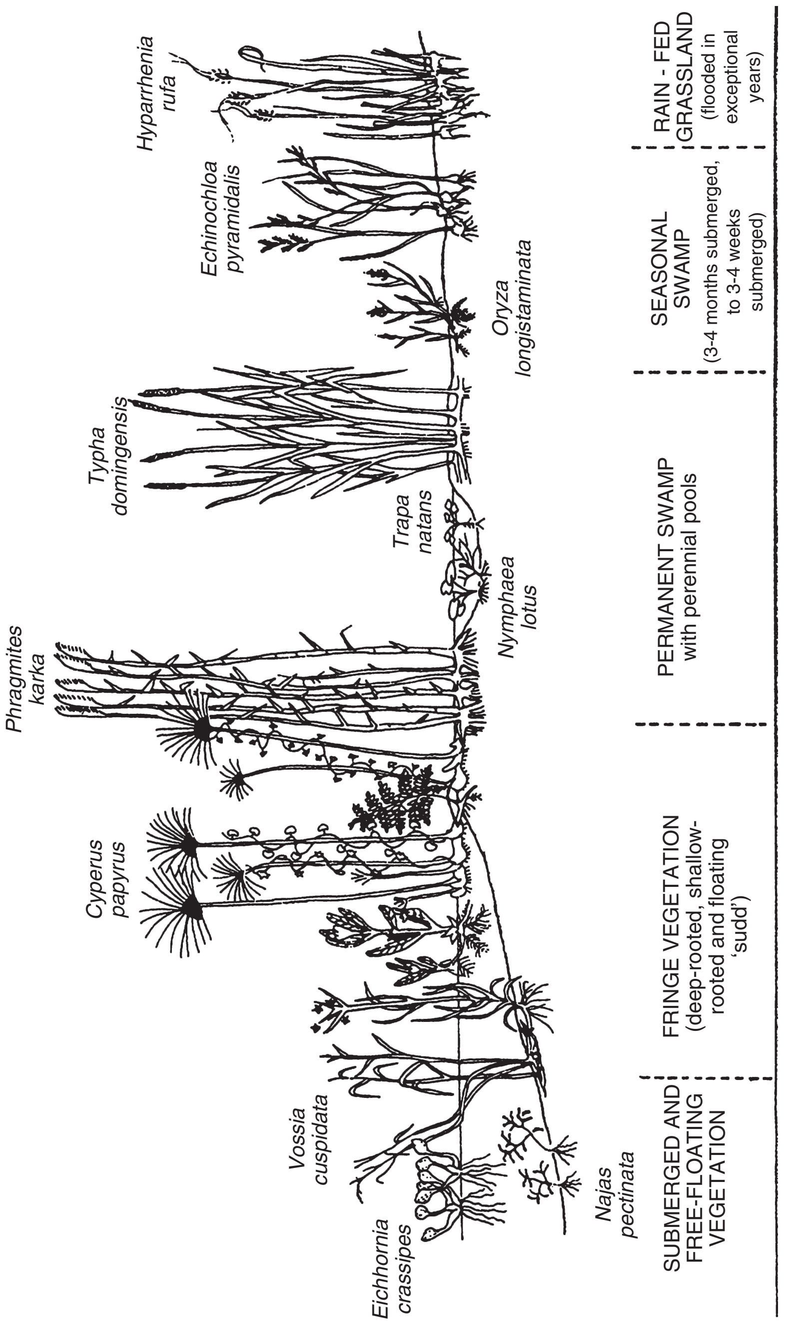

Fig. 4 A typical hydrosphere in the upper Nile Swamps of southern Sudan, showing river and wetland zonation (after Denny, 1985)

Fig. 5 *Suddia sagitifolia*, the single higher plant presumed endemic of the Sudd swamps (*see Color Plates)*

Table 1 Hydrophytes in Sudanese waters (from various sources)

No.	Family	Latin name	Distribution
1	Characaeae	*Chara globularis* (A. Br. Ex Kutz.)	CS, SS
		Nitella sp.	CS, SS
2	Azollaceae	*Azolla nilotica* Decne ex Mett.	SS
3	Isoetaceae	*Isoetes schweinfurthii*	SS
		Cyclosorus interruptus (Willd.) H.	SS
4	Marsileaceae	*Marsilea nilotica* L.	WN, SS
		M. gibba	SS
5	Parkeriaceae	*Ceratopters cornuta* (Beauv.) Lepr.	SS
6	Podocarpaceae	*Podocarpus spp*. (L'Herit) Pers.	SS
7	Alismataceae	*Alisma plantago-aquatica* L.	KF
		Limnophyton obtusifolium (L.) Miq.	CC, SS
		Burnatia enneandra M. Mitch.	CC, SS
		Caldesia reniformis (D. Don) Kakino.	EQ
		Laphotocarpus guayanensis (Kunth)	KF
		Ranalisma humile (Kunth) Hutch.	KF
		Wiesneria schweinfurthii Hook. F.	EQ
8	Aponogetonaceae	*Aponogeton subconjugatus* Schumach.	SS
		A. vallisnerioides Bak.	EQ
9	Amaranthaceae	*Alternanthera nodiflora* R. Br.	CS, SS
		A. sessilis (L.) R. Br.	WS
10	Araceae	*Pistia stratiotes* L.	SS
11	Asteraceae	*Melanthera scandens* (Schumach.)	SS
12	Ceratophyllaceae	*Ceratophyllum demersum* L.	WS

(continued)

Table 1 (continued)

No.	Family	Latin name	Distribution
13	Commelinaceae	*Commelina diffusa* Burm. F.	CC, SS
		C. benghlensis L.	RS, CS, SS
14	Convolvulaceae	*Ipomoea aquatica* Forsk.	CS, SS
		I. cairica (L.) Sweet.	CS, SS
		I. rubens (Choisy).	CS, SS
15	Cucurbitaceae	*Lufa cylindrical* (L.) M.J. Roem.	SS
16	Cyperaceae	*Cyperus alopecuroides* Rottb.	CS, SS
		C. albomarginatus	SS
		C. munditi (Nees) Kunth	CS, SS
		C. papyrus L.	SS
		Frimbristylis subaphylla Boeck.	EQ
		Scirpus cubensis Poepp. & Kunth.	CS, SS
17	Droseraceae	*Aldrovonada vesiculosa* L.	SS
18	Fabaceae	*Aeschynomene indica* L.	CS, SS
		Desmodium hirtum	SS
		Sesbania rostrata pubescens DC	SS
		Mimosa pigra L.	WS
19	Hydrocharitaceae	*Lagarosiphon schweinfurthii* Casp.	EQ
		L. cordofanus (Hochst.) Casp.	CS
		Nechamandra alternifloia (Roxb.)	WN
		Ottelia alismoides (L.) Pers.	CS
		O. ulvifolia (Planch.) Walp.	CS, SS
		O. brachyphylla (Gurke) Dandy	EQ
		O. scabra Bak.	CC, SS
		Vallisneria spiralis Fenzl.	CC, SS
20	Lentibulariaceae	*Utricularia thonningii* Schumach.	CS, SS
		U. stellaris L.	CS, SS
		U. exoleta R. Br.	CC, SS
		U. reflexa Oliv.	EQ
21	Lemnaceae	*Lemna perpusilla* Torr.	CC, SS
		L. polyriza L.	EQ
		L. aequinoctialis Welw.	EQ
		Spirodela polyrrhiza L. (Scheild).	SS
		Wolffiella hyalina (Del.) Hegelm.	DF, KF, SS
		Wolffiopsis sp. Den Hartog & Vd Plas.	SS
22	Najadaceae	*Najas pectinata* (Parl.) Magnus.	CS, SS
		N. graminea Del.	CS, EQ
		N. schweinfurthii Magnus.	EQ
23	Nymphaeaceae	*Nymphaea lotus* L.	CS, SS
		N. caerulea Sav.	CS, SS
		N. micrantha Guillem & Perrott.	CS, SS
24	Onagraceae	*Jussiaea diffusa* Forsk.	CS, SS
		Ludwigia stolonifera (Guill & Perr.)	SS
		L. leptocarpa Nutt.	CS, SS
		L. suffruticosa L.	CS, SS
25	Palmae	*Borassus aethiopicum* Mart.	CS, SS
		Hyphaene thebaica (L.)	NS, CS

(continued)

Table 1 (continued)

No.	Family	Latin name	Distribution
26	Poaceae	*Echinochloa stagnina* (Retz.) Beauv.	WS
		E. haploclada (Stapf.)	SS
		E. pyramidalis (Lam.).	CS, SS
		Phragmites karka (Retz.).	CS, SS
		Oryza brachyntha Chev. & Roehr.	EQ
		O. barthii A. Chev.	EQ
		O. longistaminata A. Chev. & Rochr.	SS
		O. punctata Kotschy ex Steud.	CS
		Panicum repens L.	CSIC, SS
		Paspalum polystachyum R. Br.	EQ
		Vossia cuspidata (Roxb.) W. Griff.	CSIC, SS
		Sporobolus pyramidalis Beauv.	CS, SS
		Hyparrhenia rufa (Nees) Stapf.	CS, SS
		Digitaria debilis (Desf.) Willd.	KF, SS
		Suddia sagitifolia Renvoize	SS
27	Polygonaceae	*Polygonum glabrum* Willd.	WS
		P. tomentosum Wild.	CS, SS
		P. limbatum Meisn.	CS, SS
		P. lanigerum R. Br.	SS
		P. senegalense Meisn.	DF, EQ
28	Pontederiaceae	*Eichhornia crassipes* (Mart.)	CS, SS
29	Potamogetonaceae	*Potamogeton crispus* L.	CS
		P. bunyonyiensis Denny & Lye	SS
		P. nodosus Poir.	CSIC
		P. pectinatus L.	CSIC
		P. perfoliatus L.	CSIC
		P. schweinfurthii A. Benn.	SS
		P. octandrus Poir.	CS, SS
		P. pubillus L.	DF
30	Scrophulariaceae	*Limnophila indica* (L.)	CS, SS
31	Trapaceae	*Trapa natans* var. *bispinosa* Roxb.	SS
32	Typhaceae	*T. angustata* Bory Chaub.	WS
		T. domingensis Pers.	SS
33	Verbenaceae	*Phyla nodiflora* (L.) Greene.	NS, SS
34	Vitiaceae	*Cayratia ibuensis* (Hook) Suessseng.	SS
35	Zannichelliaceae	*Zannichellia palustris* L.	CSIC

CS, Central Sudan; DF, Darfur; KF, Kordofan; CSIC, Central Sudan in irrigation canals; SS, South Sudan; NS, North Sudan; WS, Widespread; EQ, Equatoria.

the Imatong Mountains, South Sudan at altitudes of 2,000–3,000 m. *Chara globularis* and *Nitella* sp. are the only macroalgae present. Pteridophytes are represented by *Isoetes schweinfurthii, Marsilea* sp., *M. nubica, Ceratopters cornuta* and *Azolla nilotica* (Mackleay, 1953).

6 Life Form Diversity

Aquatic plants include both woody and herbaceous forms. Among the woody species, growing on the banks along rivers, *Acacia nilotica* (Sunut) is found on partially flooded areas. *Tamarix nilotica* is a pioneer on new-formed sandbanks. *Hyphaene thebaica* and *Faidherbia albida* (formerly *Acacia albida*) grow on riverbanks with groundwater within reach (Van Noordwijk, 1984). The only woody macrophyte found in permanent water is *Herminaria elaphroxylon* (Ambatch). The palms *Hyphaene thebaica* and *Borassus aethiopum* are distributed in grasslands which are regularly waterlogged or seasonally flooded. Denny (personal communication, 2002) also expects swamp palms such as *Phoenix* and *Raphia,* and *Ficus* spp. in the southern swamps.

The various aquatic macrophytes in the Sudan manifest five types of growth forms viz. free-floating (*Pistia stratiotes*), rootless submersed (*Ceratophyllum demersum*), rooted submersed (*Vallisneria* sp.), floating-leaved submersed (*Nymphaea lotus*), emergent (*Vossia cuspidata, Utricularia* spp.) and trailing on the water surface from the bank (*Ipomoea aquatica*). Beside these, and associated with emergent plants, are certain twiners and climbers such as *Ipomoea cairica, Luffa cylindrica* and *Cayratia ibuensis*.

7 Uses of Macrophytes

Macrophytes are used locally for food, fodder and as building materials. Denny (1985) gave a summary of the use of *E. crassipes* in Sudan: it is grazed fresh by cattle during the dry season, and serves as a mulch and fertilizer. When used as a mulch, it suppresses the growth of the major weed, *Cyperus rotundus,* and conserves soil moisture. GTZ conducted trials in Sudan to generate biogas from water hyacinth in the White Nile (Philip et al., 1983). Table 2 summarizes the uses of some aquatic plants. Emergent plants such as *Phragmites* sp. *and Typha* sp. have been used in phytoremediation, to remove dissolved solids and oil from the huge amounts of water extracted with crude oil. Aquatic macrophytes also provide shelter, food, hatching and nesting sites for other organisms. They play an important role in the gaseous balance in both the atmosphere and hydrosphere. Certain species are bio-indicators of pollution though such a claim has not been substantiated and documented in Sudan.

Denny (pers. com.) draws attention to the possible positive and important role of water hyacinth and wetland vegetation in general for the water cycle and in the rainfall pattern in Southern Sudan.

At a global level, aquatic plants are important to alleviate climate change caused by the emanation of greenhouse gases (GHGs). Aquatic plants can absorb and sequester considerable amounts of the GHGs. Within such a context, and considering the expansive wetlands in the Sudan, attention should be paid to study and quantify the contribution of Sudanese hydrophytes to reduce global warming.

Table 2 Some uses of aquatic plants in Sudan

Plant	Uses
Cyperus papyrus	Local inhabitants cut the tall stems for use as mats and roofing material. Animals graze on its umbels
Phragmites karika	Culms are used as building material and in mat making
Phragmites sp. *and Typha* sp.	Major components in phytoremediation, to purify oil-produced water
Azolla nilotica	Usually hosts the blue-green, N-fixing Anabaena azolli
Borassus aethiopium	Fishing boats are made from the tree timber. Fruits are edible.
Hyphaene thebaica	Trunks are used as building material. Fruits are edible.
Eichhornia crassipes	Grazed by animals, used as mulch and fertilizer and for the generation of biogas.
Trapa natans	The fruit is rich in starch and fat. Used as food.
Nymphaea spp.	Rhizomes and fruits are used as food by Nilotic tribes
Aeschynomene indica	Raft making
Oryza spp.	Potential rice crop

8 The Dilemma of Aquatic Plants

Diversity of aquatic macrophytes in Sudan is also manifested in the problems they face. Aquatic macrophytes have traditionally been regarded as a nuisance; in the best of cases, they have been neglected. This attitude is reflected in the fact that Sudanese aquatic macrophytes have received little scientific attention. One cannot but wonder at the absence of aquatic plants among the cash crops in a country endowed with such diverse aquatic habitats and plants. Although many records of aquatic weeds are available (Andrews, 1945; Ali, 1977; Hamdoun & Desougi, 1979; Desougi, 1980; Denny, 1984), there is no complete record of the aquatic flora of the country. Their classification is neither accurate nor complete, a problem exacerbated by the fact that local aquatic botanists are rare and there are no research programmes on aquatic ecosystems. The discovery in 1979 of the so far only endemic aquatic plant of the Sudan, the swamp grass *Suddia sagitifolia* (Renvoize et al., 1984), sharply precipitates this situation. The distribution of this remarkable monospecific genus is still imperfectly unknown. It is rhizomatous, with nodal rooting, reaches a height of 2.5 m and grows within papyrus swamp. Its enormous, 12 cm wide leaves are well adapted to function in the shade of reed swamps (Thomson, 1985) (Fig. 6).

9 Exotic Species

The most profound ecological changes in the aquatic ecosystems of the Sudan can be illustrated by the case of the Nile cabbage (*Pistia stratiotes*). Up to 1957, this species was the largest free-floater in the country. In 1957, the water hyacinth (*Eichhornia crassipes*) reached southern Sudan (Gay, 1958). By 1960, the whole White Nile from Juba to Jebel Aulia dam as well as its tributaries over a distance of 3,270 km were infested (Obeid, 1975). The native free-floating water cabbage had been pushed out and had become confined to temporary pools and small khors.

10 The Jonglei Canal

The Jonglei canal, designed to bypass the "Sudd", to conserve part of the water now lost to evapo-transpiration and seepage (see Fig. 1 and Dumont, 2009), is alleged to have significant impacts on the wetlands of southern Sudan, including their flora. Once completed and operated, it is expected to reduce the seasonally flooded grasslands. The most prone to change are the emergents. *Vossia* and *Cyperus* will retreat downstream, while a substantial reduction may be expected in the zone currently occupied by *Typha*. The seasonally flooded grasslands dominated by *Oryza longistaminata* and by *Echinochloa pyramidalis* will decrease in area by between 10% and 23% (Howell et al., 1988). The canal itself, with its regulated flow regime, would mostly encourage the spread of free-floating plants (Ali, 1977).

11 Civil Strife in the South

Civil war in the south of Sudan raged from 1956 to 1972 and broke out again in 1983. It was terminated by the signing of the Comprehensive Peace Accord in 2005. Though there is no as yet a proper assessment of the effect of war on the wetland ecosystems, one could envisage certain scenarios. The cutting of forests, inevitable as a direct action in war or as a side activity by armed troops, could have lead to serious soil erosion. This could increase sedimentation of the waterbodies, in particular lentic ones, and may cause a shift in the aquatic communities at the expense of floating and submerged species. Burning and cutting of *Papyrus*, *Phragmites* and *Typha* for access adversely affects not only these species, but also climbers and twiners associated with them.

12 Pollution

During three decades (1960–1980), a campaign to control water hyacinth with the herbicide 2, 4-D was carried out (Philip et al., 1983). Unfortunately, there was no evaluation of its impact on the aquatic ecosystem while we expect that such a practice would have also affected non-target floating *Pistia*, *Lemna*, *Wolffia* and *Spirodella*. Plants with floating leaves such as *Nymphaea* and *Limnophyton* could also be under threat. Furthermore, pesticides are generously applied annually on all irrigated agricultural schemes in the Sudan. With wind drift and excess water from the cultivated fields, pesticide residues find their way to the main Nile. Sadly, no research has been conducted on their impact on the aquatic flora.

For countless years, the wetlands of Southern Sudan have enjoyed stable conditions, with no significant anthropogenic interference. The term "stable" here has a special context. Odum (1967), cited in Denny (1984), describes wetlands as "pulse stable" ecosystems. Their stability relies on alternating "pulses" of environmental variables (in this case wet and dry phases). The communities of pulse-stable systems are characteristically resilient to change. However, recent anthropogenic activities could destabilize these systems. One serious threat is the oil extraction activities now overwhelming the Sudd region. Exploration, transportation and exportation of oil threaten the diversity of the wildlife, aquatic macrophytes and forests, as well as the hydrology of this intricate ecosystem (Springuel & Ali, 2005).

13 Conclusion

The Nile system in Sudan is rich in aquatic macrophytes. These communities exhibit remarkable diversity in phyletic constitution, range, horizontal zonation, life forms and uses. Endemism is low, with only one apparently endemic species, but studies are fragmented, and taxonomy is based on old sources. There is a need for a modern survey to document taxonomy, distribution, morphology, life forms, ecological niches, chemical composition, uses and threats. And inasmuch as global warming is now a reality, the role played by the hydrophytes of Sudan in alleviating global impacts through their ability to sequester carbon dioxide needs to be qualified and quantified. Particular emphasis is required for the Sudd region because of its high density and diversity of aquatic plants and because this pristine, pulse-stable ecosystem is under threat from oil exploitation. Now that a Comprehensive Peace Agreement, signed in 2005, has ended 22 years of civil war, and that in 2006 the Sudd has been given the status of a Ramsar site, this chapter raises an urgent plea to preserve the biodiversity of the swamp flora of southern Sudan.

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