Chapter 4: The Diversity of Freshwater Macrophytes in Sudan

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1. Introduction

This paper endeavours to highlight the diversity in Sudanese aquatic plants manifested in their habitats, distribution, phyletism, growth forms and ecological niches. The macrophytes in this paper refer to those plants that inhabit freshwater and marine habitats with the exclusion of algae.

Although aquatic plants were mentioned sporadically in reports by travelers and bird watchers to the southern stretches of the Nile system, the earliest data on aquatic plants in Sudan is attributed to Dandy (1937) in his article on the genus *Potamogeton* in Tropical Africa, where he reported seven *Potamogeton* species in the Sudan. Paradoxically, the "Sudd" which was considered as a political and a geographical barrier drew the attention of scientists to the aquatic plants that constituted this natural barrier (Migahid, 1947, 1948; Dirar, 1951; Talling, 1957). The comprehensive report by Migahid (1948) was the only real attempt to describe the vegetation of the central swamps. 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 initiated by the appearance of aquatic weeds in the Gezira irrigation scheme. Weeds started to appear only four years after gravity irrigation started to operate and a gradual build-up took place (Andrews, 1948). When the policy of intensification and diversification of cropping was adopted in the scheme, aquatic plants became a serious problem (Hamdoun & Desougi, 1979). The work of Andrews (1948) is the first that was solely dedicated to the study of aquatic macrophytes. The taxonomy, morphology and distribution of the aquatic plants in the Sudan appeared for the first time within 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 a landmark in hydrophytic studies. By its adverse impact on evapotranspiration rates, navigation, irrigation pumps, water supply, and fisheries, the water hyacinth has spurred much research into the aquatic weeds in Sudan.

As for the marine macrophytes (beyond the scope of this work), except for some consultancy study reports, there are no published studies on seagrasses in the Sudanese Red Sea coast, neither on their ecology nor on the impact of human activities on them. Most recent and significant is the study conducted by Gaib Alla (2005).

2. Habitat diversity of aquatic macrophytes

Aquatic plants occupy all freshwater and marine habitats of the Sudan . The geographical zonation in the distribution and diversity of the freshwater aquatic plants follows a N-S gradient, linked with the southward increase in rain intensity and duration. The diversity here is both 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 by virtue of their different water characteristics. In the swampy region of the southern Sudan the aquatic macrophytes exhibit a distinct horizontal zonation from the main river course to the higher land (Fig. 1). In the Red Sea coast seaweeds are an important component of the marine biota where a distinctive zonation is also noted from the coast (Gaib Alla).

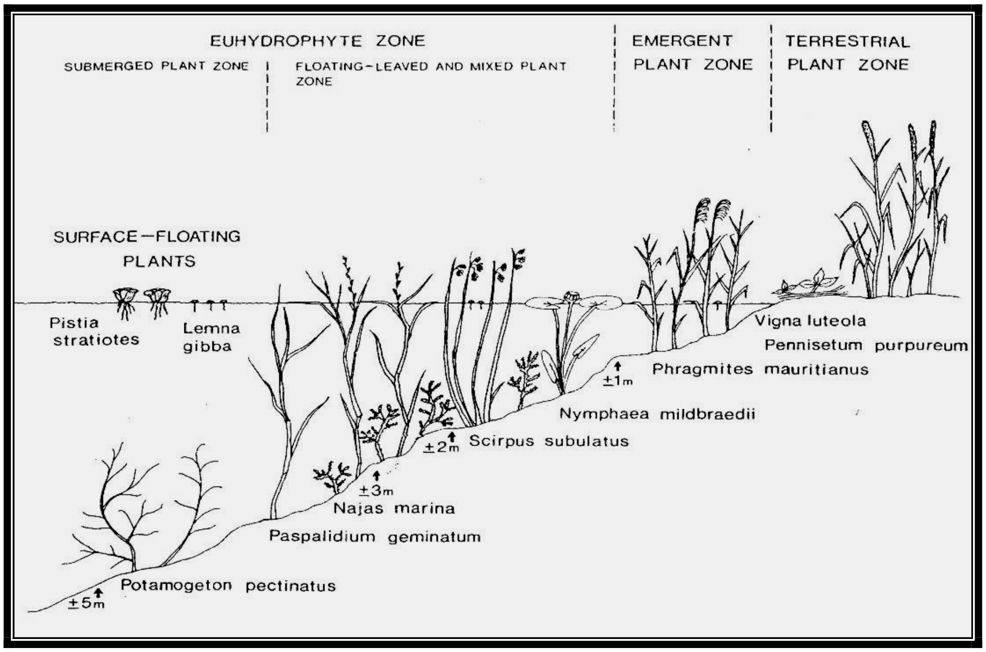

Fig. 1. Horizontal zonation of aquatic plants in Southern Sudan (Deney,1985)

3. Phyletic diversity

The aquatic plants in the Sudan belong to Pteridophyta, and Spermatophytic Gymnosperms and Angiosperms (Table 2). Denny (1985) has reported that the only wetland gymnosperm in Africa is the *Podocarpus.* It is interesting to mention here that Andrews (1950) has cited the presence of two *Podocarpus spp.* in the Imatong Mountains of Equatoria region in Southern Sudan at altitudes of 7000 and 9000 feet. Within the angiosperms, many monocots and dicots are present. *Chara globularis* and *Nitella sp.* are the only macroalgae present. Pteridophytes are represented by *Isoetyes scheinfurthii, Marsilea spp Ceratopters cornuta* and *Azolla nilotica* (Fig. 2) (Mackleay, 1953).

Fig. 2. *Azolla nilotica* within *Eichhornia crassipes* in the sheltered banks of Bahr El Gabal in Southern Sudan (Author)

4. Life form diversity

Aquatic plants in the Sudan include both woody and herbaceous forms. The woody species mainly grow on the banks along the Nile. *Acacia nilotica* grows on partially flooded areas. *Tamarix nilotica* is a pioneer tree on new-formed sandbanks. *Hyphaene thebaica* and *Faidherbia albida* (formerly *Acacia albida*) grow on riverbanks with ground water within reach (Van Noordwijk, 1984). The only woody macrophyte that is found in permanent water is *Herminaria elaphroxylon* (Ambatch). Palms that are wildly distributed in grasslands which are regularly waterlogged or seasonally flooded to shallow depth are *Hyphaene thebaica* and *Borassus aethiopum.* Denny (pers. com.) expects to find swamp palms such as *Phoenix* and *Raphia,* and *Ficus spp.* in the southern swamps.

The various life forms exhibited by aquatic macrophytes in the Sudan are fascinating. Six types of growth forms are encountered; free floating (*Pistia stratiotes, Wollffia spirodella* (Fig. 3), rootless submersed (*Ceratophyllum demersum)*, rooted submersed (*Vallisneria sp)*, floating-leaved submersed (*Nymphaea lotus)* and emergent (*Vossia cuspidata, Limnophyton obtusifolium* (Fig. 4) and trailing on water surface from bank (*Ipomoea aquatica*). Besides these life forms, and associated with the emergent plants, are certain twiners and climbers such as *Ipomoea carica, Luffa cylindrical* and *Cayratia ibuensis.*

Fig. 3. *Wollffia spirodella*, the smallest flowering plant in Sudan (Author)

Fig. 4. *Limnophyton obtusifolium,* an emergent macrophytes in the White Nile (Author)

5. Niche diversity

The niches filled by the Sudanese macrophytes are diverse. Many of them are used by the locals for food, fodder and as building materials. Denny (1985) gave a summary of the use of *E. crassipes* in Sudan being grazed fresh by cattle during the dry season, as a mulch and fertilizer. When used as mulch, it suppresses the growth of one of the major weeds in Sudan, *Cyperus rotundus,* as well as conserving soil moisture. GTZ have conducted trials in Sudan to generate biogas from the water hyacinth in the White Nile. Table (1) highlights the uses of some aquatic plants in Sudan. Recently, emergent plants especially *Phragmites* sp. and *Typha* sp. have been used in the phytoremediation project to remove dissolved solids and oil from the huge amounts of produced water extracted with crude oil in the Sudan. Aquatic macrophytes in Sudan are a tool for habitat diversification, providing suitable habitats for other organisms by the production of oxygen, provision of food, shelter, hatching and nesting.

Table 1: Some uses of aquatic plants in Sudan (Ali, 2009)

Plant	Uses
Cyprus papyrus	Tall stems are cut and used as mats. Animals graze on umbels.
Phragmites karika	Culms used as building material and mat making
Phragmites sp. and *Typha sp.*	Major components in the phytoremediation project to purify oil produced water
Azolla nilotica	Usually hosts a Blue Green , N-fixing alga: *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.
Trapa natans	Fruit is rich in starch and fat. Used as food
Nymphaea spp.	Rhizomes and fruits are used as food by the Nilotic tribes
Aeschynomene indica	Raft making
Oryza spp.	Potential rice crops

Scientists draw the attention to the possible positive and important role of water hyacinth and wetland vegetation in general in the water cycle and in the rainfall pattern in Southern Sudan. On a global level, aquatic plants are now considered important tools in the battle to alleviate the problem of climate change caused by the emanation of

GHGs. Aquatic plants can absorb and sequester considerable amounts of the GHGs. Within such a context, and considering the expansive wetlands in the Sudan, it is high time that attention is paid to study and quantify the contribution of Sudanese hydrophytes to the worldwide efforts to reduce global warming and the sequential impacts. With the carbon trade now a commonplace, there is an avenue for Sudan to tap and gain.

6. Evaluation of the Status of aquatic macrophytes in Sudan

6.1 Scientific research

Diversity as a phenomenon linked with aquatic macrophytes in Sudan is also manifested in the problems they face. Aquatic macrophytes have always been regarded as nuisance, useless organisms and at the best cases, they have always been neglected. This attitude has been reflected in the fact that the aquatic macrophytes of the Sudan have received little scientific attention, almost no attempt to utilize and of course, no policy to conserve. 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, Ali, 2009), to date there is no complete record of the aquatic flora of the Sudan. Their classification needs to be updated; even their Arabic names are not all known. This could be attributed to the remote inaccessible habitats of most of these plants, and to the infestation of there habitat with disease vectors and the fact that Sudanese aquatic botanists are rare. Also, no institutes with research programmes dedicated to aquatic ecosystems are found in the country. 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 (Fig. 8).

Fig. 8: *Suddia sagitifloia* (with broad leaves), the most recently discovered, and the only endemic, plant in southern Sudan (Author)

6.2 Exotic species

One of the most profound ecological changes that have befallen the aquatic ecosystems in the Sudan could be illustrated through the case of the Nile cabbage (*Pistia stratoites*) (Ali, 1991). Up to 1957, this species was the largest free-floater in the Nile in the Sudan. In 1957, the exotic water hyacinth (*Eichhornia crassipes*) reached the southern Sudan (Gay, 1958). By 1960 the whole stretch of the 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 phenomenon is a classical example of Gause's "Competitive Exclusion Principle" where the alien plant has wiped out the native free floating water cabbage, confining it to temporary pools and small khors.

Table 2: Hydrophytes in Sudanese Waters (from various sources)

No.	Family	Latin Name
	Pteridophytes	
1	Azollaceae	*Azolla nilotica*
2	Marsileaceae	*Marsilea nilotica*
	Gymnosperm	
3	Podocarpaceae	*Podocarpus spp.*
	Angiosperms	
4	Alismataceae	*Alisma plantago-aquatica*

		Limnophyton obtusifolium
6	Aponogetonaceae	*Aponogeton subconjugatus*
7	Amaranthaceae	*Alternanthera nodiflora*
8	Araceae	*Pistia stratiotes*
9	Asteraceae	*Melanthera scandens*
10	Ceratophyllaceae	*Ceratophyllum demersum*
11	Commelinaceae	*Commelina diffusa* Burm.
12	Convolvulaceae	*Ipomoea aquatica*
		I. cairica
13	Cucurbitaceae	*Lufa cylindrical*
14	Cyperaceae	*Cyperus alopecuroides*
		C. papyrus
16	Droseraceae	*Aldrovonada vesiculosa*
17	Fabaceae	*Aeschynomene indica*
		Mimosa pigra
18	Hydrocharitaceae	*Lagarosiphon scheinfurthii*
		Ottelia alismoides
		Vallisneria spiralis
19	Lentibulariaceae	*Utricularia thonningii*
		U. stellaris
20	Lemnaceae	*Lemna perpusilla*
		Spirodela polyrrhiza
		Wolffiella hyaline
21	Najadaceae	*Najas pectinata*
22	Nymphaeaceae	*Nymphaea lotus*
		N. caerulea
23	Onagraceae	*Jussiaea diffusa*
24	Plamae	*Borassus aethiopum*
25	Poaceae	*Echinochloa stagnina*
		Phragmites karka
		O. barthii
		O. longistaminata
		Vossia cuspidata
		Suddia sagitifolia (nomen novum)
26	Polygonaceae	*Polygonum glabrum*
27	Pontederiaceae	*Eichhornia crassipes*
28	Potamogetonaceae	*Potamogeton crispus*
		P. nodosus
		P. pectinatus
		P. perfoliatus
29	Scrophulariaceae	*Limnophila indica*
30	Trapaceae	*Trapa natans* var. *bispinosa*
31	Typhaceae	*T. angustata*

		T. domingensis
32	Verbenaceae	*Phyla nodiflora*
33	Vitiaceae	*Cayratia ibuensis*
34	Zannichelliaceae	*Zannichellia palustris*

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Chapter 5. Riverain Forests

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1. Introduction

The riverine forest reserves are composed of sunut forests along the Blue and White Niles and their tributaries in Dinder, Rahad and Khor 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 (Esmat, 2008).

Riverine forests form a unique forest ecosystem covering a vast area along river, watershed, swamps and water courses. They are of vital environmental and economic importance for the economy of the Sudan and its nature conservation. 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.

Riverine forests are a critical resource occupying the lands that are flooded when rivers rise in the latter part of the wet season. *Acacia nilotica*, which is the dominant species, is found as pure dense stands along White Nile and the Blue Nile. The species also occurs along the Dinder and Rahad rivers and in less frequently flooded basins along the Atbara River and in some inland sites.

In addition to *Acacia nilotica* (the most important in the economy of the Sudan , Jackson 1959-1960), other indigenous and exotic tree species, such as *Eucalyptus* spp., *Khaya senegalensis*, *Tectona grandis*, *Dalbergia sisso*, *Oxytenanthera abyssinica* are grown in the above mentioned areas and elsewhere.

Table 1. Total number and total areas of the riverine forest reserves in Sennar, Gezira, Blue Nile, White Nile and Gedarif States.

Working Circle	State	Name	Number of Forests	Total Area in feddans
Fuel wood	Gazira	Blue Nile sunt forest reserves	33	12423.007
Fuel wood	Sennar	Blue Nile sunt forest reserves	5	1998.099
Fuel wood	Sennar	East Sennar sunt forest reserves	59	25035
Fuel wood	Sennar	Dinder Riverine sunt forest Reserves	50	32,869.415
Sawn Timber	Sennar	Blue Nile sunt forests reserves	28	15269.143
Sawn Timber	Blue Nile	Blue Nile sunt forest reserves	16	8340.136
Sawn Timber & Firewood	Gedarif	Rahad Riverine Forest Reserves	75	83854.85
Sawn Timber & Firewood	White Nile	White Nile riverine forest reserves	16	34537
Total			282	214326.65

2. Site characteristics and conditions

The Blue Nile level starts to rise in May at the onset of the rainy season; it reaches its peaks in August which almost coincides with the time that the monthly rainfall peak is reached. The river reaches its minimum in May. Flooding of the basins follows the trend of the river floods. The high levels of the "Gerf" and "Karab" upper slopes are flooded only rarely during periods of exceptionally high floods when the river levels rise by more than 13 meters, and for very short periods. The lower slopes of the basins, however, are usually flooded for 1-3 months during July- September when the river levels peak. The "Maya" on the other hand, is usually flooded for longer periods, ranging between 5-12 months (Esmat 2008). Accordingly variations in growth conditions exist between Maya, Gerf and Karab and hence variations of species structure and composition.

The soils of the flood basins of the Blue Nile exhibit some variations from that of the clay plains. The soil can be classified into three major soil groups related to the basin topographic classes. The dominant soil of the maya is typical of the dark, cracking clays believed to have been brought from the clay plains by water run-off (Foggie, 1968). It is a black, clay soil that cracks widely in the dry season. The karab slopes are eroded slopes characterized by a high content of sand and gravel exposed as a result of erosion (Foggie, 1968). The gerif slopes on the other hand, have deep, permeable silt deposits (Fig. 1) known to be the most fertile type of soils (Booth, 1949).

Vegetation The forest type and vegetation cover in the flood basins bear some relationship to the topography, soil and flood conditions. The upper slopes of the Gerf, bear a mixture of species dominated by sunt while its lower slopes are characterized by pure stands of sunt. The associated ground flora includes *Punicum* sp and *Cassia* sp. Sparse bushes include *Zizyphus spina-christi* and *Tamarix aphylla* (Jackson, 1959).

On the Maya, due to prolonged flooding, the ground flora is absent, except for a sparse cover of a crickly-leaved mixture of herbs known collectively as terma. Mayas, which are usually flooded for over six months, are almost bare of tree cover except for scattered Sunt trees. Mayas that may be flooded for a period of 3-5 months are characterized by better sunt growth and dense terma cover. Table 2 displays the vegetation cover in the three sunt sites: Maya, Gerif and Karab areas.

Table 2. Vegetation covers in Maya, gerif and karab area.

Site type	Vegetation
Maya	crickly-leaved hoart prostate herbs " terma".
Gerif	Perennial shrubs and herbs sparsely distributed under the sunt canopy
Karab	Lower slopes close to the maya have sparse vegetation similar to that found in maya. Higher slopes have vegetation similar to that found in maya and Gerif.

3. Silvicultural treatment of ***Acacia nilotica***

Acacia nilotica is the only species well adapted to flooded basins. It requires greater soil moisture supplies than is provided by the local rainfall, a characteristic that makes regular flooding a favourable condition for its regeneration, growth and development (Booth, 1949, 1966; Foggie, 1968). These ecological characteristics of sunt have been useful in the pit sowing on the upper slopes of the Gerif and Karab or broadcasting of seeds on the regularly flooded Mayas and the lower slopes of the basins (Esmat, 2008). There is no problem of weed competition due to its elimination by the floods. Advantage is sometimes taken of the taungya system to reduce the weeding and establishment cost. These two techniques constitute the main methods of plantation establishment (Gaafar 2008).

Thinning usually commences at the age of 5-6 years from the date of establishment, with subsequent thinning every three years and the last thinning is carried out at the age 20 years. The thinning prescription of Booth (1949) was a summary of a general thinning programme. Jackson (1959) recommended heavy thinning for the first three thinning during the period of rapid height growth, and light thinning for the rest of the time. The first numerical guide to thinning practice in sunt stands was made by Foggie (1968) based on the provisional yield tables for sunt (Ahmed, 1976; Gaafar, 2008; Esmat, 2008).

The rotation age has also been a controversial subject Gaafar (2008). Booth (1949) and Foggie (1968) recommended 35 for the production of the size expected to satisfy the utilization specification. Jackson (1959) and El Tayeb (1985) suggested that 30 years could be a suitable rotation age.

4. Management system of the riverine forests

The major problem facing the management of the forests in Sudan is the achievement of self-sufficiency on a sustained basis limited area has been put under management based on sound inventories (Esmat, 2008). The main feature of Sudan forest management was based on utilization of the natural forest resources, except for some of the riverine forest plantations established along the Blue Nile and White Nile.

The working plans for riverine forest reserves along the Blue Nile, Gezira forests and for the forests reserves north of Sennar dam, Rahad sunt plantations was subject to continuous amendments. On the other hand there was no working plan made for the White Nile riverine forests and khour Abu habil forests since their reservation.

5. Current management systems

Based on the management objectives, the entire riverine forest reserves were generally divided into two working circles; the first one is the firewood working circle, which comprises the sunt plantations along the Blue Nile, south of Khartoum and down to north Sennar dam. Sunt plantations along the Dinder river, along the Rahad river north of Hawata town and the sunt plantations along the White Nile and its' tributaries in (Khour Abu habil) are all classified as part of the firewood working circle which is managed on sustained yield basis on (20years) rotation to produce fuel wood (Esmat, 2008).

The second category is the sawn timber working circle which comprises the sunt plantations along the Blue Nile, between Sennar dam in the north and Rosaries dam in the south, in addition to the sunt plantations along the Rahad River south of Hawata town in Gedarif State. The sawn timber working circle is managed on sustained yield basis on 30 years rotation to produce saw logs suitable for the railway sleepers' production in addition to other various types of sawn timber (Esmat, 2008).

6. Disturbance

Recent inventories (1986-1997) indicated a wide variation in area/age units and variation in the average number of stems per feddan in most of the forest reserves (Elsiddig 2002). Also there is an observed decline in volumes of fuel wood produced (Elsiddig and Hamid 2000).
Gaafar (2008) assessed the management of *Acacia nilotica* plantations along the Blue Nile and indicated that:

- The situation of forests structure represented by area / age gradation satisfied a good level of sustainable yield during the first rotation length (1935-1964) and up to the middle of the second rotation (1965-1994) while during the second half of the rotation (1980–1994), the situation started to deviate from normal structure at an alarming rate.
- The younger fifteen years for the period (1980–1994) represented 47.1% of the total area of the plantations, while the older fifteen years of the period (1965-1979) represented 27.7% of the total area of the plantations. This is in contrast to the situation in the first rotation (1935–1964), where the younger fifteen years plantation for the period (1950–1964) represented (42.2%) of the total area of the plantations, while the older fifteen years plantation for the period (1935 -1949) represented (54.8%).
- The area of the bare land during the first rotation was 481 ha while it was 3580 ha at the end of 2006.
- Decline of the stocking of the final crop from (125) trees per hectare to 60 - 70 stems per hectare and the decline of the average DBH may also have contributed to failure of attainment of sustainability. The deviation of *A. nilotica* plantations from normal structure and failure to attain sustainable yield is also indicated by the declining production and supply of saw logs to the saw mills.

In general the declining in managerial norms coupled with many physical and biological factors led to: ground vegetation has disappeared from extensive areas, scarcity of forests products, and decline in land productivity, in terms of age/area gradations, decrease in the number of trees per unit area, decline of the main tree size and the productivity per tree.

Factors Affecting sustainability

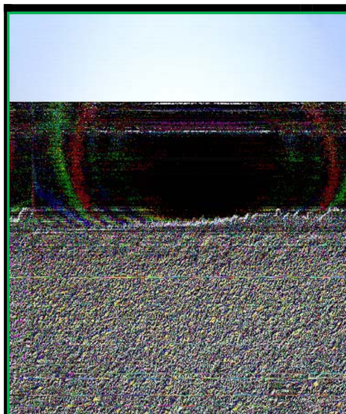
During the implementation of the different working plans, a number of factors were identified as constraints to the sustainability of the riverine forest resources and threaten their existence as a unique ecosystem. These are:

- The effect of vast clearance of natural forests led to putting more pressure on riverine forests.
- Floods (outstanding floods and poor floods).
- Banks erosion (Fig. 1) and siltation (Fig. 2).
- Man (illegal felling, encroachment, over grazin).
- Pests and diseases.
- Weeds (Fig. 3).
- Winds and thunder storms.

The FNC survey indicated that 84% of the forests in fuel wood circle suffered from farming encroachment, 90% and 77 % of the riverine forests suffer from such a problem in Sennar and the Blue Nile States respectively. The same survey indicated that siltation is one of the major problems that cause a serious disturbance that led to *A. nilotica* habitat changing particularly in Sennar State, where all riverine forests were severely affected. The siltation depth amounted to 90 to 220 cm, while, 35 % of rivernie forests in Blue Nile State were affected. Siltation seems to be a major factor that causes dieback, decline in survival rate of newly planted sunt, closing of drainage systems, loss of boundary pillars and hence disturbance of the whole ecosystem. Findings of the same survey show that bank erosion affects 3%, 10% and 35% of the riverine forests in Gezira, Sennar and Blue Nile States respectively. Dieback (Fig. 4) has been found in 11 riverine forests in Sennar and 7 forests in the Blue Nile States.

Fig. 1. Bank erosion.

Fig. 2. Siltation.



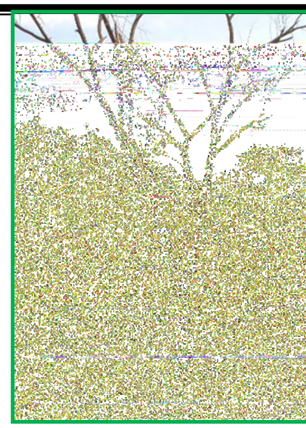


Fig. 3. weeds Fig. 4. Dieback.

7. Recommendations

7.1. There is a need for revising the conventional timber management and considering more ecologically oriented management approaches in order to consider site and site quality and various needs and interests of different stakeholders, particularly local communities.

7.2. Execution of thinning according to schedule and involvement of the local communities in thinning execution improves the management and contributes in satisfaction of communities needs.

7.3. More research is needed on problems of siltation, dieback and weed control.

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