# Merowe Dam Project. Land use and Vegetation in the Flooding Area of a planned Hydrodam in Northern Sudan

*Arnaud Malterer*

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# Abbreviations

| | |
|---|---|
| FAO | Food and Agriculture Organization |
| GIS | Geographic Information Systems |
| ha | Hectare |
| ASL | Above sea level |
| MW | Megawatt |
| SARS | Sudan Archaeological Research Society |
| WCD | World Commission on Dams |

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## *1. Introduction*

The farmers of northern Sudan have the saying: "Even our grandfathers have told us of two things, of the day of resurrection and of the dam at Hamdab". The dam at Hamdab has been talked about ever since the 1920s (Hurst 1952).

The realization of a grand project similar to the construction of the Aswan Dam which provides Egypt with its electrical power and makes the control of the inundations of the Nile further downstream possible, was implemented in northern Sudan near the community of Hamdab in 2009.

The construction work for the so-called Merowe Dam began in October 2003. Since October 2008 the 9.2km long dam with a maximum height of 67m has resulted in the inundation of the Nile Valley in the region of the Fourth Cataract[1] over a length of about 170km and a width of 4km to 13km producing a 476km² reservoir (volume of 12.5 bn m³) which has permanently flooded an ancient and unexplored cultural landscape. Since March 2009 the dam permits the production of 1250 megawatt hydropower (Lahmeyer 2011; 2012).

Under the lead of international archaeological institutions, the archaeological documentation of the area that has been inhabited by people over various periods of human history has now been completed as comprehensively as possible. Furthermore, the natural landscape including its current land use was studied and documented. The investigation reported upon here was limited to a section of the Nile Valley: the research area of the SARS Anglo-German Expedition.[2]

The scale of the Merowe Dam Project, is comparable with that of the Aswan High Dam, especially when regarding the loss of agriculturally utilised land and the magnitude of the necessary resettlement of the affected population (Table 1).

According to the planning organizations, the area between Hamdab and the Nile bend near Abu Hamed (cf. Figure 6) is the most suitable in northern Sudan for a large dam project at least when seen from the perspective of the whole of Sudan. It is the least settled and least productive section of the Nile Valley. In contrast to the wide floodplains of neighbouring regions, the valley is narrow and rocky and only few metres of the riverbank are usable as agriculturally productive land. In large sections, the bank cannot be cultivated at all (Musolf 1999; Salih 1999). It is an area of cataracts and rocks in the midst of the desert.

In spite of the designation as a multipurpose project, the primary goal of the dam project is the production of hydropower. Further, the prevention of flood damage and the irrigation of cultivated land through dam regulation are named as advantages of the project.

The negative consequences like the resettlement of about 48,000 people, the loss of a nearly unexplored natural and cultural landscape including flora and fauna, the change of the river's regime as well as the ecological consequences which are difficult to foresee stand in contrast to the advantages of the project. The fact that there were few formulated answers to these questions except for those from the planning bureau demonstrates how little public attention the project received.

There are hardly any publications concerning the current land use and vegetation of the area. The research carried out by the author sought to close this knowledge gap in the areas of land use and plant sociology for this, the least known section of the river Nile.

TABLE 1. IMPACT OF THE ASWAN HIGH DAM AND MEROWE DAM.

| | Surface Area | Maximum Volume | Lost irrigated land | Resettlement of Inhabitants |
|---|---|---|---|---|
| Aswan Dam | 5,500km² | 164 bn m³ | 10,000 ha | 100,000 |
| Merowe Dam | 700km² | 12.5 bn m³ | 12,000 ha | 48,000 |

## *2. Literature Survey*

Firstly an overview of the natural landscape of Sudan as well as general information regarding the economic situation of the population shall be given to provide an introduction to the topic. Additionally, an overview of the Merowe Dam Project as well as general problematic aspects of dam construction follows.

### 2.1 Sudan – Natural Landscape, Population and Economic Situation

#### *2.1.1 Geography*

The Republic of Sudan (Figure 1) with its capital Khartoum is situated in the north eastern part of Africa with access to the Red Sea. With a surface area of 1.8 million km², it is about five times as large as Germany. Approximately 1500km in length, it is the third largest

[1] The name given to areas of rapids with a stronger downward gradient than elsewhere along the river, caused by transverse bars of harder rock. Altogether, the Nile flows through six numbered cataracts on the way to the Mediterranean Sea (Bartl *et al*. 1998). There are however, many other named cataracts.

[2] The SARS Anglo-German expedition to the Fourth Cataract was a component of the Merowe Dam Archaeological Salvage Project (MDASP) and was coordinated by the Sudan Archaeological Research Society London (SARS) in conjunction with the British Museum and the Sudan's National Cooperation for Antiquities and Museums (NCAM). The expedition with a team of international experts and volunteers in which the author participated took place between November 2003 and February 2004 under the direction of Dr Pawel Wolf. It was made possible through grants from the British Institute of Eastern Africa and the Schweiz Department für Auswärtige Angelegenheiten.


*Figure 1. General Map of Sudan (Brockhaus 2012).*

African country extending from the Sahara in the north to the semi-arid savannahs in the south. To the north, the country borders Egypt, to the east Eritrea and Ethiopia, to the south the Republic of South Sudan and to the west Central Africa, Chad and Libya. The north-eastern border is marked by the Red Sea along a coastline of approximately 800km (Brockhaus 2012).

### *2.1.2 Natural Environment*

Sudan is a tropical country (Figure 2). It stretches from the Libyan and Nubian deserts in the north, across the semi-deserts and dwarf thorny shrubs savannahs of the Sahel Zone to the dry savannahs in the south (El Tom 1975; Adac Verlag 1998). The relief of Sudan is defined by the landscape of the Nile basin and its marginal mountain ranges. There are the Red Sea Hills adjacent to the Red Sea, The Nuba Mountains and the Jebel Marra range in the west (max. 3088m asl). A large portion of the Nile's waters evaporate in the floodplains and swamps of the Sudd in the Republic of South Sudan. The River Nile enters Sudan near Malakal and continues through the wide and flat clay plains of the semi-desert and joins with the Blue Nile, coming from Ethiopia, at Khartoum. The combined Nile then crosses the desert northwards where it is a vital artery for the scarce population. Apart from smaller areas in west Darfur and by the Red Sea, all Sudan's landscape zones are located within the drainage area of the Nile which imparts a slightly easterly axis to the country (Tietze 1973).

The vegetation varies between scarce plant cover in the arid deserts, thorny shrubs and high grass ecosystems (Sahel region). The fauna includes gazelle, desert fox, hyena, hyraxes and birds of prey (Adac Verlag 1998).


*Figure 2. Vegetation zones in Sudan (adapted from Tietze 1973).*

### *2.1.3 Climate*

High temperatures and summer rains mark the tropical climate of Sudan. Like the duration of the rainy season (April to November), the amount of precipitation decreases from south to north. In the south, annual precipitation reaches 500-700mm while only reaching 165mm in the central parts around Khartoum and stays below 25mm/year in the north. In the arid deserts of northern Sudan, precipitation falls very irregularly or is absent altogether for several years (Brockhaus 2012).

Monthly average temperatures lie between 24° C and 32° C and increase towards the south because of the cold winter nights in the deserts (Table 2). Thus, the average temperature in January lies between 16° C in the north and 29° C in the south. Average temperatures in July range from 35° C in the north to 25° C in the south. Temperatures above 50° C are not uncommon in the areas around Wadi Halfa in the extreme north in summer. Severe sandstorms (*Haboub*) occur in northern Sudan immediately before the rainy season (Tietze 1973).

### *2.1.4 Population*

According to information from the Auswärtiges Amt (2012), 38.3 million inhabitants currently populate Sudan at a density of 20.3 inhabitants/km². The desert regions in the north are almost uninhabited. About eight million people live in the greater metropolitan area of Khartoum which consists of the administrative centres of Khartoum, Bahri and Omdurman. They make up more than 33% of the whole urban population.

The Sudanese population consists of a large number of different ethnic groups with a corresponding number of different languages. (Auswärtiges Amt 2012). According to Mattes (1993), 572 ethnic groups which can be categorized into four main groups live in Sudan.

Arabs and Arab-mixed groups in northern and central Sudan (40% of the population)

TABLE 2. CLIMATE DATA OF SUDAN NORTH TO SOUTH (DATA FROM DIFFERENT TIME PERIODS) (WESTERMANN 1973, AUTHOR'S COMPILATION).

| Climate Data | Annual Medium Temperature (°C) | Maximum Monthly Average (°C) | Minimum Monthly Average (°C) | Annual Amplitude (°C) | Average Annual Precipitation (mm) |
|---|---|---|---|---|---|
| **Wadi Halfa** | 25.7 | 32.2 | 15.9 | 16.3 | 0.1 |
| **Khartoum** | 29.6 | 33.6 | 23.2 | 10 | 163 |
| **Malakal** | 28 | 31 | 26.2 | 4 | 826 |

Black Africans, e.g. the Fur tribes (Province of Darfur) and the Nuba tribes (Kordofan)

Nubians (10%), in the settlement areas of the northern Nile valley and the province of Kassala (eastern Sudan); Muslim

Beja and Rashid tribes (7%), nomads migrated from Saudi-Arabia in the regions between the Red Sea and Nubia; Muslim

In the region of the Fourth Cataract there are sedentary nomads who have switched to agriculture. According to Beck (1997), three Nubian ethnic groups, who began to settle in the region in the early 19th century, lived there and were affected by the resettlement of the dam project (Figure 5):

the Manasir (about 30,000) in the central region
the Shaiqiyya (about 20,000) from Hamdab to Amri
the Rubatab (under 5,000) in the area of Abu Hamed

*2.1.5 Economic Situation*

Agriculture

The most important economic sector of Sudan is agriculture (Embassy of the Republic of Sudan 2013). The export of cotton, cultivated mainly in the irrigated regions between the White and the Blue Nile, plays an important role (Embassy of the Republic of Sudan 2013). The agricultural activities of northern Sudan are restricted to the narrow river oasis of the Nile where date palms, grains and legumes are produced mainly for subsistence. Irrigation projects and cultivation programs are designed to aid the expansion and improve productivity in the agriculture sector.

*2.1.6 The Energy Problem*

The extension of the energy sector plays a central role because it is seen as the main driver of other economic sectors. Prior to the construction of the Merowe Dam Sudan generated its totally insufficient energy supplies of about 1000 MW through the combustion of charcoal (80%). Energy supplies from oil and hydropower made up the other 20% (Auswärtiges Amt 2012).

To alleviate the energy problem the use of new energy sources is required like hydropower which has an estimated potential of 3000 MW of which only 10% were used (280 MW in Rosseires, 12.6 MW in Kashm el-Girba, 15 MW in Sennar) and fossil energy sources. Large reservoirs of oil and natural gas are known in western Sudan (Embassy of the Republic of Sudan 2004).

Furthermore, renewable energy sources such as solar and wind power could be used. However, they are not suitable on a large commercial scale because of the lack of investment capital.

Sudan possesses a high potential for utilization of energy sources whose development and use could reduce the major problems in rural and peripheral, undersupplied regions tremendously (Mattes 1993). It is against this background that the Merowe Dam was planned to bring relief (Figure 3) (Lahmeyer International 2004).

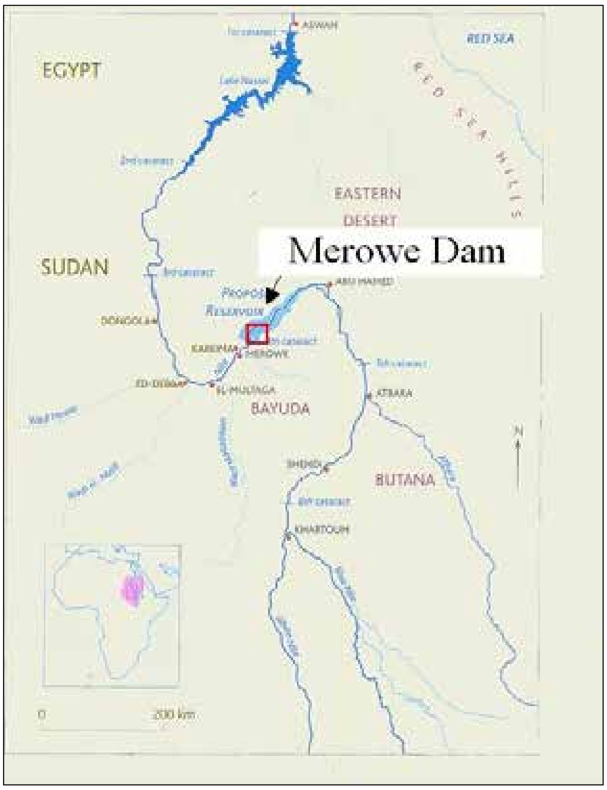


*Figure 3. Location of the dam (Lahmeyer 2004). Since 2009, the dam is in operation.*

*Plate 1. View of the Merowe-Dam Construction Site.*

*Plate 2. Location of the planned retaining wall across Mirowy Island from the summit of Jebel Kulgeili (Photo D. A. Welsby).*

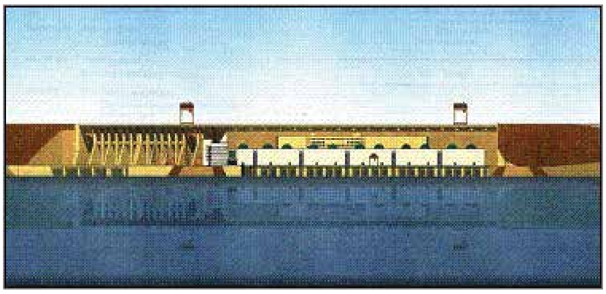

*Figure 4. Design of the dam (Diagram: Lahmeyer International 2004).*

## 2.2 The Merowe Dam Project

The idea for the construction of a Nile dam in northern Sudan goes back to the 1920s (Hurst 1952). After the financing, which was feasible following rising oil exports and foreign investments, had been organized, the planning stage of the dam began in August 1999 (Askouri 2004).

The primary goal of the Merowe Dam project is power production. Five long distance power supply lines cross the Bayuda Desert to the cities of Khartoum, Bahri, Omdurman, Atbara, Port Sudan, Dongola, Merowe and ed-Debba with electricity (Salah 2004). Furthermore, irrigation areas have and will be created (Peninou 2004).

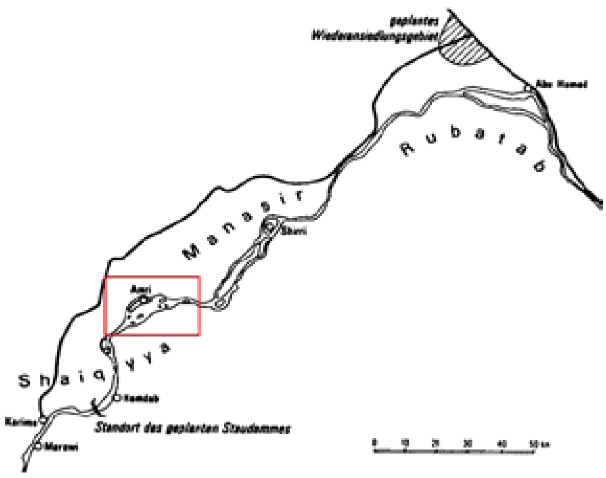


*Figure 5. Population groups at the Fourth Cataract affected by the Merowe Dam project. The red border shows the investigation area (adapted from Beck 1997).*

The Merowe Dam reservoir resulted in the relocation of more than 60 settlements. Almost exclusively, these were of farmers who make a living from small, highly fragmented irrigation plots and date palm plantations.

*3. Natural Characteristics of the Investigation Area*

### 3.1 Site Description

The investigation area (Figure 6) lies within the region of Amri and includes all the islands in the Nile between the settlements of Dar el-Arab and et-Tereif near the provincial boundary between Northern and Nile State. It includes the southerly bank of the river up to the limits of the reservoir (cf. Figure 7).

The area, of about 150km², is difficult of access with only rough tracks. Two thirds of it consist of hostile desert

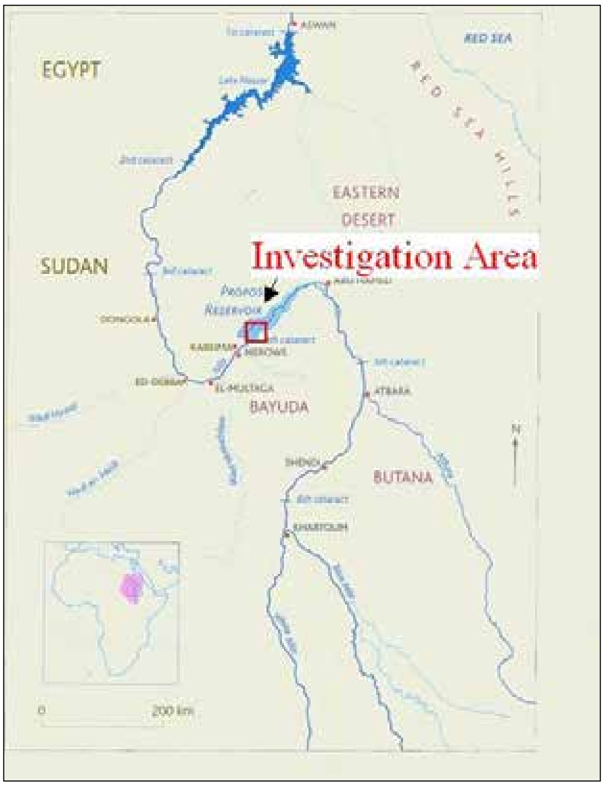


*Figure 6. Location of the investigation area in the reservoir created by the Merowe Dam at the Fourth Cataract (adapted from Salah 2004).*

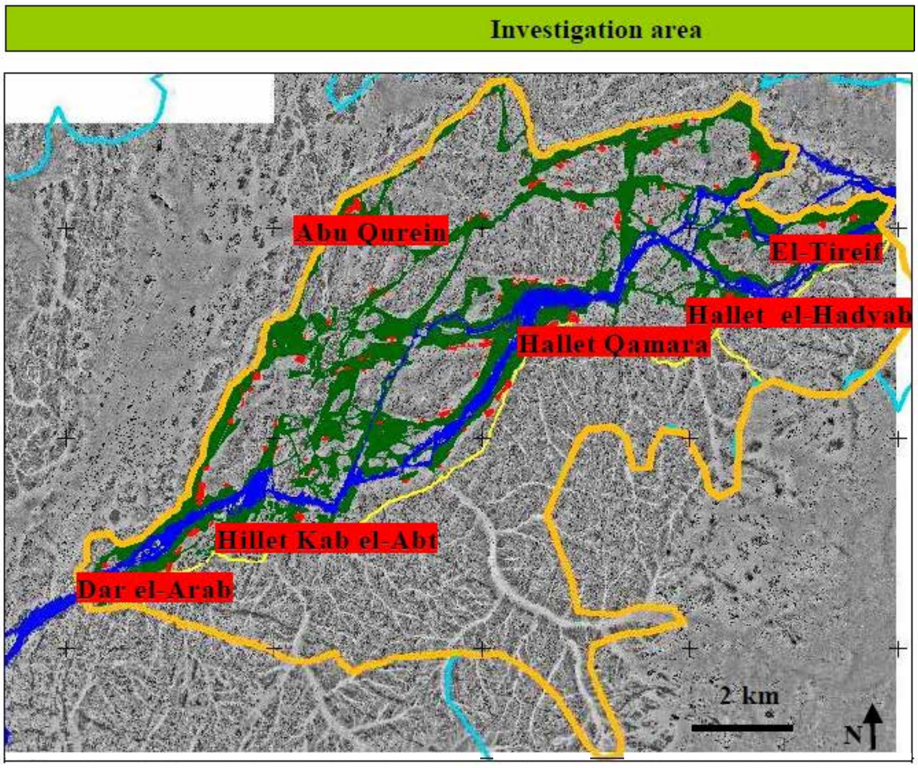


*Figure 7. Overview map of the investigation area. Legend: orange = limits of the IA, light blue = maximum extension of the planned reservoir, dark blue= course of the Nile, green = agriculturally used land, red = settlements, yellow = sand and gravel tracks, grey = rock desert (also cf. Map 1, Appendix F) (Malterer 2005).*

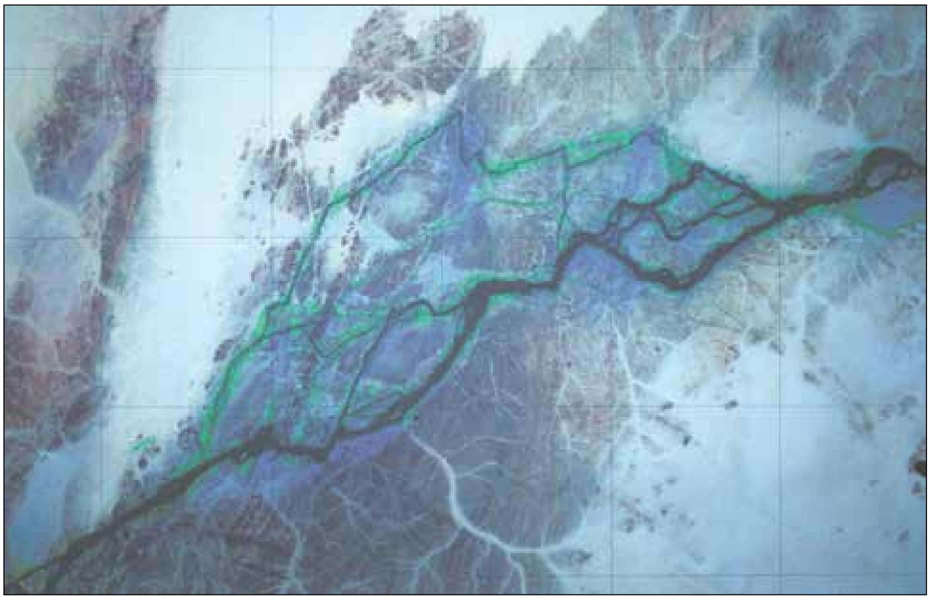

*Plate 3. Satellite image of the investigation area. Simplified interpretation: green = cultivated area, black = course of the Nile, blue = gneiss, black = granite, red = sandstone, white = sand desert and* wadis *(Satellite image, Ministry of Irrigation and Water Resources Sudan 2004).*

areas devoid of any vegetation (Figure 7, Plate 3). The dam is located about 25km downstream. Starting from there, a newly paved road connects the dam with the town of Merowe.

Viewed from a wider perspective, the area is on the southern edge of the Sahara. Here, the Nile, flowing in south-westerly direction between Abu Hamed and ed-Debba, forms the borderline between the Nubian Desert in the north and the Bayuda Desert in the south. The latter slowly merges with the semi-desert area of the Sahel Zone.

### 3.2 Relief

According to Ahrendt (1997), the landscape along the Fourth Cataract which merges into the desert, can be classified roughly into four geomorphologic units: basement, different fossil terraces, lose sand dunes and recent *wadis.*[3]

The Fourth Cataract, just like the other five numbered cataracts of the Nile between Aswan and Khartoum, is characterised by the emergence of crystalline basement to the surface. The river is forced to flow around the hard cores of primitive rock which form great obstacles. This is displayed by the presence of the diverse island structure with numerous river channels and the typical cataracts. In the investigation area alone, several hundred islands exist; some of them tiny. Most of these are not used and are uninhabited due to their small size and their mainly rocky surface (Salih 1999).

The Nile is accompanied by a small strip of floodplain which directly borders the desert. In some places the Nile

[3] Usually waterless river valleys in the desert which carry water only after heavy rainfall events (Bartl *et al*. 1998).

Valley only opens to one side of the river where it forms floodplains. In some sections the river banks drop relatively sharply into the river making agriculture impossible.

According to the relief and the seasonal wind directions, the Fourth Cataract is increasingly being covered by quaternary sediments from the adjacent deserts from northerly and southerly directions. This process is clearly visible on satellite imagery (cf. Plate 3); the numerous *wadis* which cut through the strongly jagged rock- and stone desert are also visible. This is characterised by bizarre ridges (maximum height 60m), highly piled mountains of debris, alluvial covered valleys, gravel terraces, sand dunes and open plains in areas of compacted sand. Aside from the quaternary sediments, all surface areas are covered by material of the debris- and gravel fraction, by rocks and by boulders which in turn are covered by a mostly light to dark grey patina (desert varnish).

By the Nile smoothed and hollowed rock surfaces form a geomorphological specialty. Gabriel and Wolf (2005) called them ‘whirlpools’ and ‘potholes’. They were even found in side valleys of the Nile, the so-called palaeochannels which dried up long ago. They testify that the ancient course of the Nile must have been much wider than today’s at least at certain periods.

The altitude of the investigation area is between 254m asl at the river margin near Dar el-Arab and 324m asl in the upstream part near et-Tereif. The full storage level of the Merowe Dam is at exactly 300m asl and as it is to be expected that some ridges attaining a greater elevation are not completely flooded and remain as isolated islands.

### 3.3 Climate and Water Budget

The climate at the Fourth Cataract is determined by extreme drought and high daily temperatures. According to El Tom (1975) (cf. also Wickens 1975), in this area, the Nile flows through parts of the hyper-arid desert[4] with hot and dry summers, mild winters and episodical summer rains. Ayyad and Ghabbour (1986) state that precipitation from 25mm to 50mm/year can be expected in the months of July and August but that the rains often completely fail or that much less rain falls. Thus, the average annual precipitation in Abu Hamed (cf. Figure 8) is 10mm/year (Mühr 2000) and 34mm/year in Kareima (Knapp 1973). The rest of the year is dominated by total drought which is caused by the dry, in winter cold, north-easterly wind


*Figure 8. Climate diagram: average monthly medium from long-term averages (1961-1990) at the Fourth Cataract based on the climate station at Abu Hamed (Mühr 2000).*

[4] Deserts are defined such, when average precipitation is lower than 100mm/year. Drought areas with 100mm up to 250mm/year are defined as semi-deserts (cf. Dittrich 1983; Knapp 1973).

out of the Nubian Desert. Warm, strong sandstorms (*Haboubs*) from the south usually occur shortly before the beginning of the rainy season (Salih 1999).

The medium annual temperature is 29.3° C. The average daily maximum of 46° C is reached in the hottest month of June. In winter, medium temperatures fall to about 20° C in January. The medium daily maximum in January is 12.6° C, the absolute minimum has been measured at 3.5° C and reflects the cold winter nights (Knapp 1973; Mühr 2000).[5]

The water level of the Nile depends on the annual course of the north equatorial rainy season. The level of the Nile rises between May and October caused by the strong rainfall in the upper reaches. The floods usually reach the Fourth Cataract in July and induce the dynamics of a changed river system. The sudden excess of water spreads into the completely dried up side branches and isolates the formerly accessible islands from the mainland. Although many of the small rock islands in the main stream are completely flooded, they are preserved due to

*Plate 4. Cataracts and countless islands characterise the Nile between Kareima and Abu Hamed.*

their resistant mineralogical buildup. The water-deposited mud provides the basis for the cultivation of legumes, cereals and vegetables between the larger islands after the flood season. The higher bodies of water that are trapped and thereby retained even after the floods recede, the so-called high-flood-channels, are used for the irrigation of the terraces until the next flood season.

The waters of the Nile reach their lowest level in June, shortly before the high floods. At the same time the maximal fertile floodplains area for the cultivation of crops is revealed. Although the vertical difference between high and low water levels varies annually, it has averaged about 8m during the last decades which can be documented by the washed-out steep river banks according to Salih (1999). The characteristic palm groves of the Nile Valley with their irrigated valley terraces can also be considered as the upper limits of the flood.

There is no documented evidence on the depth of the Nile at the Fourth Cataract in the literature. The heterogeneous relief of the river bed, which is interrupted by granite and gneiss rocks, does not allow a definite statement. A measurement with a water gauge at a 170m-wide gorge section undertaken by the Anglo-German team gave

[5] Data of temperature and humidity are drawn from the climate station in Kareima, about 50km south west of the investigation area.

a depth of 48m. According to some statements of villagers, there are supposed to be parts of the river where the depth reaches 100m.

Between 60 and 70 bn m² of water pass through the Fourth Cataract each year, a large part of it during high flood season between July and October (Salih 1999; Beck 1997).

The cataracts are a characteristic feature of the whole year. The fact that the Nile carries water all year round makes settlement and agriculture along the fertile banks possible. At the same time is the limiting factor that the water only reaches several meters from the river in most places. This limitation is overcome by the numerous irrigation channels (Plates 14-16) which supply areas with water that are not flooded naturally. The rare summer rains ensure a thin but constant vegetation cover in the *wadis*. According to Dittrich (1983), acacia trees that grow in the region mark scarce and irregular subterranean water horizons which they must reach with their deep root system (up to 35m).

### 3.4 Geology and Soil Conditions

The Fourth Cataract can be distinguished by the emergence of a Precambrian basement of mainly granite and gneiss at the surface, the so-called Basement Complex. It determines the morphology of the region with its rough, strongly rifted hilly rock and boulder landscape (Vail 1978). The sand dunes of the immediately adjacent deserts and the sediment rock formations of the Nubian sandstone, typical for northern Sudan, surround the Fourth Cataract.

The rock complexes are partially covered by fluvial and aeolian sedimentation; recent quaternary sediments of sand, clay and mud (Figure 9). These are the Nile Valley floodplains, the *wadi*-beds, the gravel terraces and the sand dunes.

The rock ridges covered by a grey patina are disrupted by rocks like amphibolites, quartzite, mica slate, basalt, graphite and pegmatite (Vail 1978). The more easily eroded metamorphic rocks (mainly gneiss consisting of biotite, quartz and feldspar) form readily visible features which follow the Nile from a north-easterly to a south-westerly direction. This characteristic is clearly visible through the blue highlighting on the satellite image in Plate 3. In contrast to gneiss, distinguishable by its rough, slate-like structure, the wind- and water-eroded granite complexes present a smooth, rounded surface. Often they occur as conical hills formed of plies of loose rock boulders. The more easily eroded gneiss, in great parts once having formed the higher river bank, can be found in the rather plain undulating but bizarre landscape of low rocky ridges that often extend in straight lines and various directions (Gabriel and Wolf 2005). Two eroded, round mountains of basalt consisting of loose eroded debris near the mouth of the *wadi* known as Khor Tannerowi illustrate the geological heterogeneity of the region.

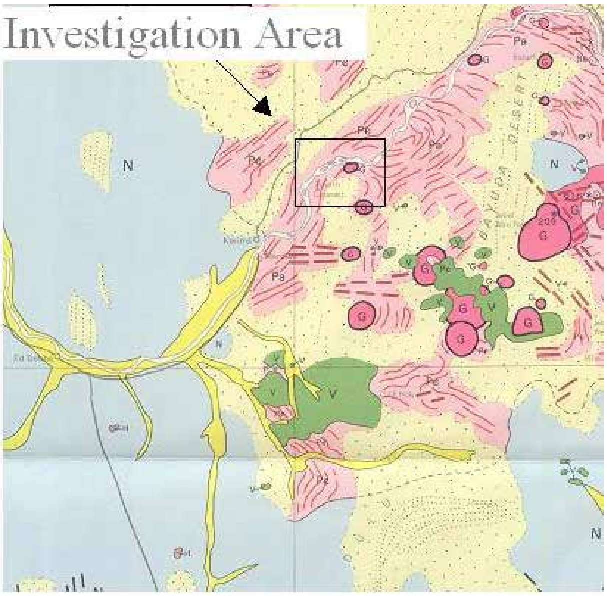


*Figure 9. Geological map of the Fourth Cataract (adapted from Vail 1978).*

Due to the extreme drought at the Fourth Cataract, the essential characteristics of a genuine pedogenesis are lacking. Soil types in arid and hyper-arid deserts are defined as soil-like formations according to Ganssen (1968). Other authors call them desert-soils, azonal soils or regosols (Knapp 1973). The alluvial soils in the Nile floodplains are of very recent origin and are characterised by periodical relocation processes which are caused by the annual floods. The loamy alluvial soils have a high clay fraction and are, during low water levels, the essential basis for the cultivation of crops which need neither artificial irrigation nor fertilizer. The sediments of Nile mud have a thickness of several meters in some places; it is documented by the washed-out steep river banks. Different soil horizons are not recognisable on the homogenous floodplain soils. Thus, it cannot be defined as a process of genuine pedogenesis.

Kellogg (1960) classifies the areas outside the river oases as a zone of grey desert soils (sierozems). They are given different names according to their grain size composition. Thus, in the investigation area, 'Hamada' desert soils, gravel deserts and sand desert soils occur; they often merge into one another. They are almost exclusively bare of any vegetation and are subject to aeolian and episodic fluvial processes.

The gravel deserts, also called 'Serir', are composed of gravel material with grain sizes between 2-10mm in diameter at and near the surface. They occupy the largest surface area in the region and predominate on hillsides, flat hilltops and open plains. They form the erosion debris of the neighbouring rock formations that protrude through the surface

The 'Hamada' layers of the debris desert, which are found near the surface, mainly or almost exclusively consist of coarse rocks and gravel which cover fine-grained material. They are accompanied by hills of debris and rock surfaces that show erosion crusts and occur on Pleistocene gravel terraces near the river as well as along the bases of rocky ridges in the hinterland.

The sand desert soils or sand dunes (ergs) dominate the northern part of the investigation area (e.g. Amri Island). These are the most recent aeolian sediments, exclusively having been formed by sedimentation of drifting sand. Due to the constant relocation processes, pedogenesis is not visible.

The water-carrying *wadi*-beds have a special role after episodical extreme rainfall events. They are filled with gravel and loose sand and are strongly silhouetted colour-wise against their surroundings due to the lack of coarse rocks and the sparse grass and thorny shrub vegetation (cf. Schmidt 1998).

The higher, dried-up side valleys (palaeochannels) that were once also flooded by the Nile, show a palaeoclimatically interesting soil formation. Thick sand, silt and clay sediments with traces of hardened lime precipitations (kankar) and the plant roots and shells document, according to Gabriel and Wolf (2005), the once wider river bed of the Nile during a climatically more favourable time span, the so-called pluvial period of the early to mid Holocene (10,000-3,000 BC) . Soil profiles observed in loam pits, several hundred metres from the Nile also document that the river occupied a wider bed in this region. Here, lime precipitations, oxidation and reduction characteristics in the b-horizon point to groundwater and backwater influence (gleying).[6]

## *4. Goals and Objectives*

It was the aim of the research reported upon here to document the current land use as well as the existing, dominant native vegetation at the Fourth Cataract before its permanent inundation. Land use at the Fourth Cataract is mainly driven by agricultural production, therefore this work is focussed on the topic of agriculture.

The focal points of the research are:

The investigation of agriculture and other activities (fisheries, use of raw materials including wood, settlements and infrastructure).

The inventory of the native vegetation including its growth area and its uses.

## *5. Methodology*

The objectives suggested certain steps which will be described in detail below.

### 5.1 Analysis of Literature, Maps and Aerial Photographs

A comprehensive analysis of literature from primary and secondary sources makes up the basis of the work. German, English and French publications were integrated. Apart from written sources, internet sources were also used.

High-resolution black and white aerial photos (digital orthophotos, resolution 0.5m) were a valuable resource for the identification of land use and vegetation. Maps were created on the basis of these aerial photos in combination with terrestrial visits and mapping and also photo interpretation. They were designed with the help of geographical information systems (GIS ArcView 3.2). The inventory of settlements and infrastructure as well as the demarcation of land use units (cf. Figure 5) almost all result from the interpretation of aerial photos.

### 5.2 Empiric Investigation of Land use

The inventory of land use in the area is based on two scientific research methods, **questioning** and **personal observation** as empiric investigative methods. Empiric investigation refers to the systematic inventory and interpretation of phenomena. Empiric means to test the theoretically formulated thesis in reality. Systematic means to apply certain rules and regulations in the investigation (Atteslander 2000). The empiric investigation was conducted in December 2003 and January 2004.

The use of interviews in questions relating to land use was very effective in this case because there are few or no theoretical databases. Atteslander (2000) differentiates between various forms of questioning. In the work at hand use was made of the partly structured questioning in the form of a conversation guideline (compare Appendix A). Conversations were held using questions prepared in the form of notes and where the order of questions was left open.

Emphases of the interrogation were mainly agricultural topics as described in the chapter on agriculture. Especially necessary were questions that were – at this point in time or due to the short stay in the region – not observable (e.g. questions concerning crop rotation and the different cultivation seasons). Questions relating to wood, other raw material use and fishery were also treated within the partly structured questioning.

The persons interviewed were two English-speaking school teachers of the settlement of Dar el-Arab who also work as farmers. For a large portion of the interviews, Mohammed Ahmed el-Ajami was present.

Part of the empiric investigation is based on personal observations in the field, supported by the use and analysis of aerial photos. Observation is defined as the systematic uptake, documentation and interpretation of reality, according to König (1973).

The observations concentrate on the area around Dar el-Arab (cf. Figures 5 and 7). It was possible to find answers to questions concerning the range of cultivation, types of cultivation, methods of cultivation, animal production and use of wood/raw materials. Field visits were conducted on all used plots there. Observations in the rest of the investigation area were reduced to randomly selected sectors of the mainland and islands if they were used agriculturally.

### 5.3 Inventory of Native Vegetation

The inventory of the wild growing, native vegetation in the investigation (including the inventory of weeds) was done by mapping in the field using vegetation keys for the identification of plants.[7] Two vegetation units were defined with regard to their their water requirements:

the river-oasis vegetation of the periodically flooded Nile floodplains

the xeromorph desert vegetation of the valley terraces,

[6] The process whereby the iron in soils and sediments is bacterially reduced under anaerobic conditions and concentrated in a restricted horizon within the soil profile. Gleying usually occurs where there is a high water table or where an iron pan forms low down in the soil profile and prevents run-off, with the result that the upper horizons remain wet. Gleyed soils are typically green, blue, or grey in colour.

[7] Field guide: Bebawi and Neugebohrn 1991; Maydell 1990; Ozenda 1977; Dittrich 1983.

*wadis* and sand dunes

Later, a classification of the vegetation into **plant communities**[8] as sub-organised vegetation units was undertaken. They were then in turn organised into **plant societies**[9] according to Knapp (1973). The plant sociological classification of the scientifically proven plant societies and their scientific definition is mainly based on criteria of species composition[10] that also relate to specific habitat conditions. The author's MA thesis (Malterer 2006) presents more detailed information on the plant communities and their plant societies especially with regard to their species composition, distribution in the investigation area, structure, habitat conditions, economic significance and anthropogenic influence. Information on the regional use of some of the plant species was derived from an interview with Mohammed Ahmed el-Ajami. General and additional information on plant sociology (geography, general habitat characteristics, ecology, super-regional economic significance etc.) were derived from the following bibliography: Bebawi and Neugebohrn 1991, Knapp 1973, Musolf 1999 and Maydell Von 1990. The extent of the descriptions depends on their abundance and predominance. The denomination of plant societies follows Knapp (1973) and is based on characteristic and physiognomically striking plant species, their habitat distribution and habitat conditions.

The nomenclature of the plant communities in this study uses the same criteria with some adaptions to better characterise the regional vegetation of the Fourth Cataract.

The mapping of the native vegetation was limited to the winter months of December 2003 and January 2004, in the dry season. Thus, it cannot be concluded that the inventory of the desert vegetation is complete although an attempt was made to also classify desiccated plants. Nonetheless, it can be expected that bulbs, seeds or shoots of further xerophytes stay underground until they begin to germinate after a precipitation event (Dittrich 1983).

The use of land as pasture and deforestation, erosion and climate warming, all of which has been going on for centuries, makes it difficult to identify the vegetation in its natural form along the Fourth Cataract. Therefore, the definition of "wild growing" refers to the currently growing, native and immigrant or introduced vegetation which has adapted to the land and pasture use at Fourth Cataract. Cultivated agricultural plants are discussed separately in the chapter on agriculture. The weedy vegetation in the irrigated fields and palm groves has been noted only to a limited extent.

An overview on plant communities and the associated plant societies with the character species can be found in Appendix E in the form of a table. Another table in Appendix C lists the vegetation of the region in alphabetical order divided by growth form with the proper plant family and the Arab, English and German names, if available. A third table in Appendix D classifies the vegetation by its habitat.

Two vegetation maps which have been created in GIS and which are presented here provide overview of plant cover and species composition in two selected parts of the study area, one in the river oasis and one in the desert. It was attempted to choose two parts that represent a diverse and typical vegetation as well as the most native. The following steps were necessary for the mapping and map creation:

Selection of two sections of vegetation that have representative, natural flora from aerial photos and field visits. At least two categories of plant societies should be present.

Demarcation of the sections to be inventoried

Magasir Island: complete island surface area. The Nile is the border of the plot.

Wadi Um Keleit: a section of 1km in a *wadi*-bed including its watershed (dry gullies) up to 100m, and tributaries up to 200m.

Inventory of the vegetation by inspection in the field

Registration of plants onto the aerial photos

Digitalization of the vegetation plots and points with the aid of GIS ArcView 3.2

## *6. Results*

### 6.1 Land Use in the Investigation Area

Land use at the Fourth Cataract (Figure 10) is dominated by agricultural production. The agricultural sector, therefore, forms one of the focal points of this study. Apart from that, information about other forms of land use (fisheries, wood- and resource use, settlements and infrastructure) is also presented. The intensity of treatment in the author's study (2006) followed the surface area and importance of each sector. For an overview map as well as a detailed map see Figures 5 and 7.

#### *6.1.1 Agriculture*

Agriculture in the study area is an oases economy and is sustained by the work of small farming families. The Nile here crosses regions with desert climates, therefore agriculture depends on artificial irrigation and Nile floods. Access to land, which is cultivated on narrow, highly fragmented fields in the floodplains and in the irrigated palm groves on the valley terraces and in the palaeochannels[11] forms the basis of life for the Manasir and Shaiqiyya that settle here. Predominantly they are farmers who grow mainly date palms, cereals, vegetables, legumes, fruits, alfalfa, alexandrian clover and spices in traditional ways with simple irrigation technologies. These products are grown for private use, animal fodder and for the local market. Raising livestock also plays an important role and is a permanent part of production. Predominent are

[8] Plant community is any conjunction of plants which live in a certain uniform area of the earth, which exist in an interdependent relation to each other and the conditions of their habitat and which thus create their own environment (Sukacev 1954)..

[9] Plant societies are returning and competing combinations of plant species which occur under similar environmental conditions (Knauer 1981)..

[10] Defined by characteristic and differential species, also by dominant species (according to Knapp 1973).

[11] *Wadis* are the dried up side arms of the Nile which today are not flooded by the Nile anymore. Even terrain and great sedimentary deposits create good conditions for irrigation.

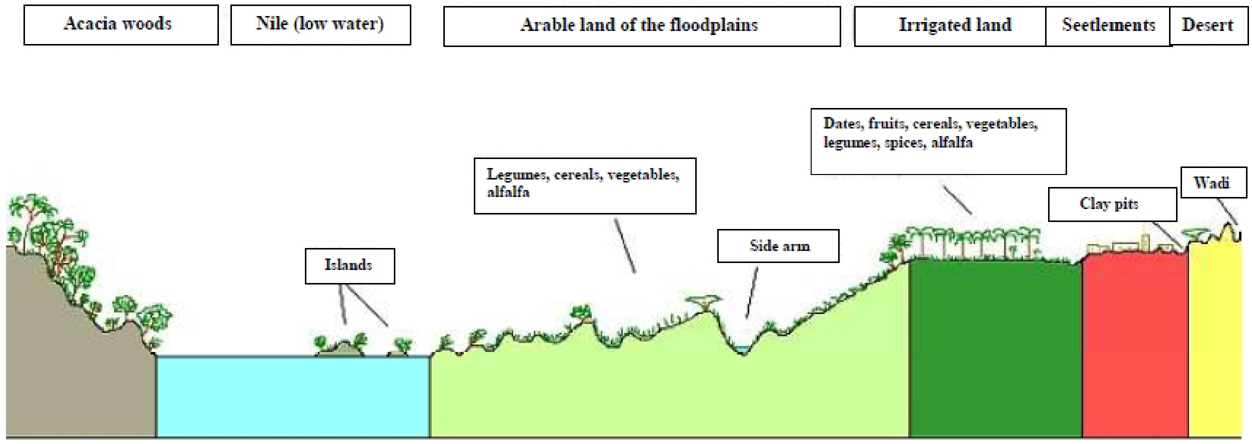


*Figure 10. Area use in the investigation area at the Fourth Cataract: cross-section through the Nile Valley near Dar el-Arab (Malterer 2005) (cf. Figure 12).*

donkeys, goats and sheep. Beyond that, cattle, mules, chicken and camels are kept. The cultivation of field crops as well as the date and fruit production are operated manually on fertile strips of several hundred metres wide between river, desert and rock. It is the most important form of land use in the region. It is limited strictly by the hostile rocky terrain. This reduces the opportunities of cultivation of the used sites (Plate 5).

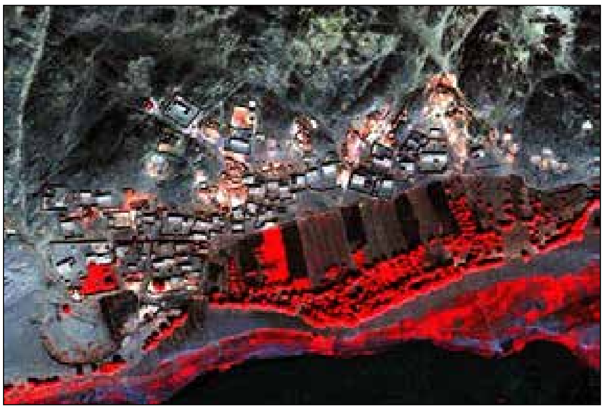

*Plate 5. Typical land use situation at the Fourth Cataract (Boni Island): Quickbird – satellite image. Bottom to top: Nile, Flooded land with fields on remaining soil moisture, irrigated land and palm groves of the valley terraces, settlements and desert (Dhiel 2005).*

<u>6.1.1.1 Economy and Development of the Landscape</u>

The current agricultural use of the region by the Manasir and Shaiqiyya began at the beginning of the 20th century with the settling of nomads. After the introduction of simple technologies by the colonial power, diesel-driven irrigation pumps began to replace the oxen-driven water wheels (*saqia*) in 1970. Newly introduced plants like wheat cultivars and okra provided the basis for a wider range of cultivation, which improved supply safety. The access to fertilizers and chemicals for plant protection produced an increase in yield. Automobiles took over a large part of the necessary transport to the local markets and thereby almost completely substituted camel transport.

In spite of some progress, the conditions for a modernised agriculture have remained underdeveloped until today. The main cause is the hostile topography of the territory which does not allow for large-scale, mechanised cultivation. Apart from irrigation pumps, no machines nor technical tools are used. Diesel is in short supply and has to be obtained from the nearest town in jerry cans or barrels. The introduction of diesel driven irrigation pumps has remained the only important impact on traditional agriculture. At the same time it requires higher investments.

The current forms of economic action are subsistence – and on a small scale a goods-producing agriculture. The goods produced do not cover all the needs of the farming families, therefore it cannot be defined as complete subsistence farming. Surplus products such as dates, onions, millet, spices and livestock are sold on the local market. This makes it possible to buy simple tools, food, gas for cooking, fertilizer, fuel and spare parts for the irrigation pumps. The cultivation and offer of agricultural products depends on market demands, private needs and cultivation conditions (size of fields, number of pumps available, fuel, pest infestations) and on the number of livestock. In order to minimize the impacts of crop failures and falling market prices, a diverse range of products is cultivated.

<u>6.1.1.2 Areas and Structures of Cultivation</u>

The agriculturally usable fields are limited to narrow strips, about 100m to 300m wide, on both sides of the Nile and to narrow palaeochannels (cf. Figure 7, Plate 3). Generally, two cultivation areas can be distinguished by their type of water supply:

**Irrigated field- and palm groves on valley terraces and palaeochannels**

These fields are located parallel to the valley on the high plateaus of the river terraces and palaeochannels which are not naturally flooded and are irrigated with diesel pumps, pipelines and channel systems with Nile water. They are cultivated all year round during three seasons. The fields are set up between a dense network of channels in neighbouring parcels 10-50m² in size. They are bordered by earth walls. The fields are located either under the open sky or under the shade of date palm trees (Plate 6), which take up about 40% to 50% of all arable land in the irrigation zone. The favourable climate in the palm groves (shade and moisture) is mainly used for the cultivation of okra, horse- and black-eyed peas, sorghum- and pearl millet, alfalfa and alexandrian clover, wheat and spices in form of the so-called 3-level-cultivation.[12] These species form the ground level. Fruit trees like mango, guava, citrus, banana, wood-producing and shade species (Neem tree, soapberry tree) form the intermediate level.

*Plate 6. Open palm grove before seeding of wheat.*

Date palm trees and the odd dom palm dominate these two levels and form the third level of the palm grove land (Plate 7). These groves are found along large parts of the river oases of the Nile in northern Sudan and are its characteristic feature.

Where terrain and capacity of the irrigation pumps allow, more fields are worked on other sites farther from the river behind the palm plantations. They are not shaded and directly border the desert. They are cultivated with

*Plate 7. Irrigated palm grove in a* wadi.

the same species as in the date palm groves. This is the so-called *saqia*-land requires the greatest cultivation efforts, because the necessary water needs to be diverted over long distances. To maximised the benefits of these additional efforts, agricultural plants are also planted alongside the channels (Date palm trees, peas, black-eyed peas) in order to make the best possible use of the water.

Isolated *saqia*-fields can be found on sites which are separated from the Nile by rocky hills and where the water needs to be pumped 'over the hill'. Due to the required energy input, many of those remote fields remain fallow. An attempt to produce the highest yields with the least input, is done by intensifying cultivation (fertilization) instead of creating new fields. Arable land and fuel for its irrigation are both in short supply.

**Naturally flooded, arable land in the floodplains of the Nile**

The river, its banks, slopes and seasonal channels are flooded between July and September, caused by summer rainfall in the Ethiopian highlands and consequently get covered by fertile Nile sediments. The nutritious, water saturated soils are used for the cultivation of black-eyed peas and pearl millet, sorghum-millet, wheat, vegetables, alfalfa, alexandrian clover, spices and lupines in the following months up to the beginning of the next flooding period (Plates 8 and 9).

It is not an exaggeration to say that almost every piece of land, even if it be steep and rocky, is used (Plate 10). Even the smallest of the Nile islands are visited by boat to seed two or three rows of black-eyed peas and pearl

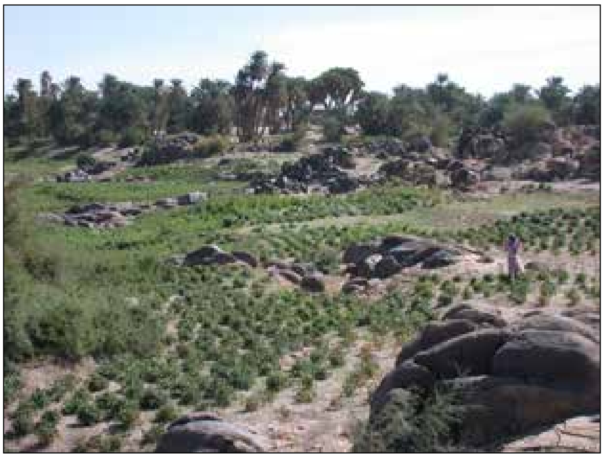

*Plate 8. Beans and pearl millet in immediate neighbourhood of the Nile floodplains. Rocks strongly limit agriculture here.*

*Plate 9. Fields next to the river.*

millet in between the rocks. It is understandable, considering that the working input is low. The loamy, nutritious, muddy soils ensures a constant yield, independent of the economic input while artificial irrigation is unnecessary.

The fields in the floodplains grow in size with decreas-

[12] According to Dittrich (1983).

*Plate 10. Use of steep river banks for cultivation of black-eyed peas and pearl millet.*

*Plate 12. Cultivation of a larger field.*

ing water levels and reach their maximum extent in June, shortly before the flood season (Plate 11). At that point, the cultivated area in the floodplains takes up more than half of all arable land in the region.

*Plate 11. Freshly seeded alfalfa field shortly after the drying up of a side branch of the Nile.*

The range of cultivated species nearly corresponds to that to be found in the irrigated fields with the exception of trees like date palms and fruit trees which cannot be grown in the floodplains as they do not tolerate flooding. Therefore the 3-level-cultivation is restricted to the palm groves of the unflooded high fields.

6.1.1.3 Cultivation Methods and Irrigation

The cultivation of fields is mainly based on traditional methods which provide the area with three cultivation seasons. Simple mechanical tools are used. The preparation of the seed bed is done manually by hoe. The soil is turned over, weeds are killed, earth walls constructed and the irrigation of the single plots regulated using the hoe. On larger fields, oxen are used in front of a home-made plough (Plates 12 and 13). Seeding is done manually in rows into the prepared, loose soil. After the seeds are pressed into the soil, it becomes necessary to regularly flood the fields in the upper irrigation sector with Nile water.

This is done using diesel irrigation pumps and pipelines to transport water (during low floods up a slope of 8-10m) onto a high level from where the fields are irrigated through a network of channels by gravity feed. Water

*Plate 13. Field plots of wheat in the Nile using oxen and plough on the island of Um Duras's floodplains.*

from the river and from pools left after the flood[13] is used.

The pumped water is primarily led into a main channel and from there distributed to side channels and aqueducts in order to guarantee a calm water flow. Using local knowledge and methods, the small fields are interconnected in the best possible way to the channel system.

The fields are kept as small as possible. Oftentimes, the rocky river banks require the constructions of very long channels, which are directed to the arable fields in the hinterland via high embankments, rock cuttings and wooden aqueducts (Plates 14-15). Occasionally metal oil barrels are used to form the channels of some aqueducts.

Irrigation technology is an essential part of the regional agriculture. It is the precondition for gaining new arable land and for the cultivation of economically beneficial trade products such as dates. The technology is based on the locally developed skills and methods. Farmers try to maintain a high proportion of mud in the pumped water in order to avoid degradation or salination of the soils, even by manually spreading mud onto the fields. By contrast, irrigation is never necessary in the floodplains. Water supply is guaranteed by the remaining soil moisture from the flooding season.

Irrigation and the operation and maintenance of the diesel pumps is exclusively done by male family members (Plate 16). Not every household owns its own pumps,

[13] Water bodies on the flood plains isolated from the river that are filled during high floods.

*Plate 14. An irrigation channel on a high embankment to supply remote fields in the desert.*

*Plate 15. Irrigation channel crossing a wooden aqueduct, date plantations in the background.*

often a few households have to share a pump. In order to supply all fields with water, the pumps usually need to run from the early morning to dusk.

6.1.1.4 Range of Species and Crop Rotation

The range of cultivated species is very diverse in the region (Table 3). Fertile soils, year-round water supply from the Nile, many hours of sunshine and a lack of frosts ensure the production of numerous species at all times of the year. Apart from palm trees and other perennial species, the range of species in the irrigated plots corresponds to that of the floodplains. The cultivation of palm trees and other woody species (fruit trees, pigeon peas, karkade, neem) is restricted to the irrigated land, because these species do not tolerate flooding of from several weeks to months.

As mentioned before, numerous flower-bed-species are grown in small plots in the irrigated fields and the palm groves and also on the floodplains along the Nile. The selection of species and quantity depend on personal needs and demand in the local market, soil quality and costs of seed material. The cultivation of these crops in the study area is done during three different seasons in a defined crop rotation. Cultivation begins in September at the end of flood season and ends in July when the next flood season begins. The growth of vegetables, legumes, pearl millet and clover are mainly set for the autumn and winter months (September-January). A large part of the fields is reserved for the cultivation of wheat between January and April. Sorghum fields dominate the landscape of the region in the hot summer months of April to July.

*Plate 16. Regulation of irrigation using a hoe (photo Heinrich Barth Stiftung 2004).*

TABLE 3. TYPICAL CROP ROTATION AT THE FOURTH CATARACT.

| Crop Rotation | Time Period of Cultivation |
|---|---|
| Legumes, Vegetables, Pearl Millet, Clover, Okra | September - January |
| Wheat, Okra | January - April |
| Sorghum-Millet | April - July |

6.1.1.5 Cultivated Species

**Date and Fruit Trees**

**Date** palm (*Phoenix dactylifera*) is the most important agricultural species of the arid river oases and dates are the most important product throughout the Fourth Cataract. The trees are mainly female and are planted in rows about 10-20m apart, in plantations with about six varieties (e.g. Gundailya, Barakawi). The fruit, usually between 20-60kg/tree is harvested around October. To ensure sufficient crops and speed up fertilization, farmers place one male palm leaf into each female crown at the beginning of the year. They also facilitate vegetative reproduction. To do this, branches from the lower parts of the trunk are separated from the mother tree and planted elsewhere. Irrigation of these trees is done individually within an earth bank or together with the irrigation of the fields. Each household owns between 15-25 date palms. The average annual income of one household is about 10 sacks (about 900kg). The sacks of dates are picked up by trucks after a period of storage and taken to Khartoum for further processing. In the region they are the most important trade product but are also used in the individual households. The date palms fulfil an irreplaceable function by providing wood and palm leaves which are used for roof construction, fencing and the cover of livestock pens. Another function is their shading

*Plate 17. Young guava under date palms.*

*Plate 18. Field plots with horse beans in a palm grove.*

effect on ground crops. Fruit trees like guava (Plate 17), mango, orange, lemon and sporadically also banana are grown individually or in groups to provide for family needs. In the palm groves, they are located on the second level under the date palms and are irrigated together with the ground crops. In the face of the promised financial compensation of fruit trees in the framework of resettlement, numerous new plantations of young fruit trees can be found in the area.

**Legumes**

The production of legumes is very common in the area. Being a nitrifying plant, they are of great importance as a keeper of soil fertility and as an important primary species to be planted ahead of depleting species like wheat and sorghum-millet.

The **black-eyed pea** (*Vigna unguiculata*), often cultivated in conjunction with pearl millet, is one of the most widespread agricultural species, area-wise. Main production areas are the slopes of the Nile floodplains. It is seeded at the beginning of September and provides fodder, rich in proteins (pods and leaves) for livestock during the winter months. Until January, the fields are harvested almost daily. During Ramadan, the species is also consumed by humans. Black-eyed peas are relatively modest. They do not need fertilization and survives over longer periods of time without irrigation. Their roots and leaves cover the ground almost completely and thus protect the fields from erosion; they are often situated on steep river banks.

**Horse bean** (*Vigna faba*) is the most important food in northern Sudan. It is cultivated in the palm groves and the floodplains (Plate 18) but can currently only cover subsistence demands due to low market prices. It is also produced during the winter months.

Planted in hedges as wind breaks and as an important food source in the area, **pigeon pea** (*Cajanus cajan*) is a yellow-flowering shrub with tiny, lentil-like seeds which are used to prepare 'Adispap'. The shrub is only to be found on irrigated land.

**White Lupine** (*Lupinus termis*) is cultivated as fodder mainly on floodplain fields. The dried seeds are also cooked and consumed by humans.

**Cereals**

Cereal production for bread-making and animal feed, being an important staple food in the region, is covered through the cultivation of three cereal species.[14]

**Pearl millet** (*Pennisetum glaucum*) is used as an important feed for livestock and is preferably cultivated in the Nile floodplains. The reason why pearl millet is usually seeded together with black-eyed peas is based on an old tradition which relates to the positive characteristics of these species influencing each other's growth (shading and nitrification). Pearl millet, cultivated between September and January, is salt tolerant and very resistant to drought.

The main crop of the second season and the most important bread cereal is **wheat** (*Triticum aestivum*) which is seeded towards January and harvested around April. Cultivation is mostly done on larger, fields (50-100m²) in monocultures.

The globally important millet cereal **Sorghum** (*Sorghum bicolor*) is a crop of the third season during the hot summer months from April to June and the last main crop before the beginning of the 'possible' rainy season or arrival of the floods. During that time, a major part of the agricultural fields in the floodplains is utilised for sorghum. The blades up to 4m in height are an important animal fodder and are furthermore used as straw bedding for livestock. The cereal is an essential basis for bread making and other foods and is, together with dates, the most important cash crop of the region depending, of course, on suitable market prices.

**Vegetables**

One of the dominant vegetables in the study area is **Okra** (*Abelmoschus esculentus*). This annual species that dies after its maduration is seeded at the beginning of September and can be harvested until February. A second rotation in February ensures year-round yields. The long, at the ends pointed, pods turn brown during maduration (Plate 19) and play an important role as a supplement in many meals. Surpluses are sold on the local market.

In open, unshaded plots, **onions** and **tomatoes** are often cultivated on low earth banks to be sold on the local

[14] There was no evidence to suggest the use of barley.

*Plate 19. Okra pods shortly before maduration.*

market and for personal consumption. Their cultivation season is during the winter months as for all vegetable species and legumes; harvest is in February. Larger tomato fields can be found on the island of Um Duras for example.

Further vegetable species like **aubergine, cucumber, paprika** and **yams** (*Ipomoes batatas*) are mainly grown for personal consumption.

**Spices**

The economic importance of the cultivation of spices differs locally. Fennel and dill are grown as market products for example on the island of Um Goz. **Chilies, pepper, rucola** and **basil** can often be found along the edges of fields. The sepals of **karkade** (*Hibiscus sabdariffa*) are used to prepare a refreshing drink or tea.

**Green fodder**

**Alfalfa** (*Medicago sativa*) and **Alexandrian clover** (*Trifolium alexandrinum*) form the basic fodder supply for livestock husbandry. With good irrigation, a successful harvest can be guaranteed over a time period of six to seven years. Several bundles are cut almost daily and transported by donkey to the homesteads where the animals are kept. Clover and alfalfa are either directly used as fresh, green fodder or the protein-rich seeds are crushed and used as seed material or stored to be later on mixed into the fodder. The period of cultivation is from September to January with three or more harvests per year.

**Wood and shade trees**

**Neem** (*Melia indica*) has an important role being a drought resistant wood and shade supplier in the region. The tree species, an immigrant from India and Burma, is planted in the fields and the palm groves as well as in settlements. The wood is used as fuel, the leaves are supposed to drive away insects.

The **soap berry tree** (*Balanites aegyptiaca*), being a naturally occurring as well as a planted tree species in the settlements serves to provide shade and for wood and fruit production (cf. 6.2.3).

6.1.1.6 Plant Protection and fertilization

The major part of the fertile river sediments are left behind in the process of pumping water to the fields and palm groves. For that reason, demanding species like wheat, millet, horse beans and onions are fertilized using artificial fertilizer or animal dung (Plate 20). Salty or degraded soils are managed by spreading river sediments in the form of mud or by intensively irrigating those fields with muddy water to regenerate sufficient soil fertility. Salt tolerant species like sorghum or wheat are thereafter planted on these sites.

Weeds like *Mimosa pigra*, *Striga hermonthica* and *Cistanche philypaea* are combated mechanically. During locust and mice infestations, chemicals are applied in the millet and clover fields. Because there are no governmental subsidies, some farmers are forced to take up loans from the bank to buy fertilizer and chemicals for plant protection.

*Plate 20. Applying phosphate fertilizer to young horse beans.*

6.1.1.7 Ownership and tenure

Most households in the region own on average 0.25ha. The farmers state that this is not always sufficient to cover a family's needs or to provide a surplus to sell. The tight social networks in the villages, the family relations as well as migration of young men as migrant workers[15] nonetheless largely ensures a basic supply of all families. Due to an incomplete register of property which was done at the beginning of the 20$^{th}$ century, land tenure conflicts between villages arise every now and then. Large fields of the *saqia*-land near Dar el-Arab has not been farmed for several years because of such a conflict.

While the fields in the irrigated land are under private ownership of the individual households, the fields on the Nile floodplains and arable land on uninhabited, small islands are newly distributed as common land to the communities every year. Thus, each household has the right to use this territory. The supervision of ownership and tenure rights is done by the 'mayor' or the village council.

6.1.1.8 Livestock husbandry

Farming and animal husbandry are strongly connected. Animal and crop production play equally important roles

[15] The older brother usually returns on the death of his father when the fields have become unoccupied.

in the economy of the Fourth Cataract. The animals are used to transport and haul cargo. Growing animals is an essential part of the local economy to ensure food supply and as a lucrative source of income on the market in Merowe. Furthermore, livestock serve to produce organic fertilizer.

Goats, sheep and cattle (Plate 21) are grown for meat and milk production. Chickens are also present in almost all households. Oxen, mules and donkeys are used as draft animals in agriculture. The donkey is the most important pack animal and has an irreplaceable role as a local means of transport for harvested products, water, construction materials and people. Camels are only seldom used for transport nowadays (Plate 22). They are mainly used for long distance transport of cargo for example to the local market in Merowe. However, they are being replaced by all-terrain trucks. The large scale camel breeding which used to be common outside of the Nile Valley until a few decades ago hardly plays a role today. Nomads no longer live in the study area. Despite increasing motorisation, the donkey remains the most important means of transportation.

*Plate 21. Cattle husbandry.*

The average household owns about 10 sheep, five goats, six chickens and one or two donkeys. Due to the high fodder needs, cattle farming is on a relatively small scale. Also, the use of cattle in agriculture is not worthwhile on the small fields.

The type of animal husbandry and the feeding methods is based on local traditions and conditions. While camels feed on leaves and ground vegetation which they can find around where they are tied up, goats and sheep receive their fodder in closed pens. These are walled by mud bricks or rocks and covered by primitive roof constructions made of palm fronds and shrubs to provide some shade (Plate 23). The pens are located in close proximity to the households at the edge of the desert. Cattle is also kept in walled pens or, tied up on straw bedding. Donkeys usually get an isolated spot and straw bedding. While not at work, they are tied up on a short rope attached to a peg.

*Plate 22. A camel transporting heavy water cans.*

Fodder supply is mainly the responsibility of female family members and is a relatively time-consuming process. Fresh green fodder needs to be picked from the fields and transported to the remote homesteads by pack animals (Plate 24). The fodder consists mainly of alfalfa, millet, black-eyed peas and the harvest leftovers of horse beans, wheat, okra and other cultivated plants. Additionally, animals are fed with lupines and the fruit of the dom palm. Alfalfa and Alexandrian clover are the only plants which are exclusively cultivated for animal feed. Harvesting in the fields is done daily using simple knives. Alfalfa is either fed directly of threshed to separate the seeds which are stored for later feeding. Legumes are another important basic fodder during the winter months. During the hot summer months, grasses and cobs of sorghum millet cover the animal's fodder demands.

*Plate 23. Sheep in an animal pen.*

*Plate 24. Alfalfa harvest. Care of the animals is mainly done by women.*

*6.1.2 Fishery*

Fishery along the Fourth Cataract plays a rather small role. The simplest techniques are used to catch fish. Nets, tied to plastic bottles are thrown into the water from rowing boats in the river sections with the strongest currents (Plate 25). Recovery of the nets happens the following day. The daily catch is small but sufficient for the supply of the village households. A professional fisherman from Dar el-Arab stated that the yield of fish has been decreasing steadily. There are about 10 fish species that are caught, among them perch and carp

Fishery on a larger scale (motorised trawl net fishery) is not possible due to the numerous cataracts and rock and sand deposits.

*Plate 25. Fisherman, pulling in the nets.*

*6.1.3 Use of raw materials and wood*

Apart from mud, taken from open pits for house construction (Plate 26), there are no known repositories of important raw materials in the region. The habitants stated nonetheless that gold has been found in small amounts in the sediments of the Nile between 1919 and 1994, possibly even before that time.[16] It used to be sold in Kareima. For a professional gold washer it was possible to recover by sieving 1-2g of gold per week.

Loose stones from the rubble in the bordering rock desert are used as construction material for houses and for the construction and enclosure of irrigation channels. Furthermore they serve to reinforce fields in terrace cultivation and are used in the construction of walls and boundaries.

The acquisition of wood as an essential construction material is based on the limited wood resources in the area. It is limited to the palm trees (date and dom) in the plantations and wild-growing, sparse tree and shrubby vegetation like the different acacia species (Plate 27), soap berry, giant milk weed, neems, tamarisk and others in the floodplains and *wadis*. Except for date palms there is no replantation in the area; therefore the wood resources are rapidly decreasing. In the face of the resettlement from the area, sustainable forest management is not being considered. The harvest of trees on private property may be decided by the owner while the use of wild-growing trees and shrubs is regulated locally. Compare section 6.1.2 and 6.1.3 for the use of the different woody species.

*Plate 26. Mud bricks spread out for open air drying next to the quarry pits.*

*Plate 27. Freshly cut acacia trees for wood production.*

*6.1.4 Settlements*

The location and structure of the settlements is adapted to the geomorphology and distance to the nearest available water source. Therefore, the villages are located in the immediate vicinity of the Nile and its side branches on flat valley terraces, usually behind the fields and palm groves. Close proximity to the water is essential to agriculture, thus the villages are situated in the non-arable, mostly bare area without any vegetation.

Due to the varying terrain in the region, the houses are built in clusters in some areas and widely separated in others. All houses are built in the traditional mud-brick architecture.[17] They are covered by flat roof construc-

[16] For evidence for Kerma period gold working on the right bank of the Nile in this region see Emberling and Williams 2010.

[17] Cf. Haberlah and Bussche Von Dem 2005 for more about architecture and settlement structures at the Fourth Cataract; also Welsh http://www.sudarchrs.org.uk/.........

*Plate 28. Simple mud-brick houses between the river and the rocky desert.*

*Plate 29. View from the desert into the settlement of Dar el-Arab.*

tions made of palm trunks and fronds and are usually surrounded by a large, walled courtyard. Some inner courtyards are shaded by solitary shade trees (soap berry, neem, dom). The loamy material for the bricks is extracted from pits locally, mixed with water, dung and straw and then dried in the sun (Plate 26).

The households have neither power nor water supply. Despite this, some public buildings like the village store produce power through diesel-powered generators to run a deep freezer, a light bulb or a TV. Faeces and sewage are in places disposed of in deep pits, but most houses have no toilets and people defecate in the surrounding desert. The small amount of rubbish is burned or deposited in pits or on hillsides.

Public buildings in the villages include a primary school, a simple mosque, sometimes a mill (et-Tereif) and at least one store that sells basic foods (bread, drinks, rice etc.) and household appliances.

#### *6.1.5 Infrastructure*

In contrast to the larger settlements of the region on the southern bank of the river (Dar el-Arab, Hillet Kab el-Abd, Um Keleit, Hallet Qamara, Hallet et-Hadyab, et-Tereif) which are connected by a vehicle track, most of the villages on the large islands (e.g. Amri, Um Duras, Kandi, Um Kambatut, Um Gebeir, Ishashi) can only be reached by rowing boat particularly during the flood season. Some of the islands like Um Duras are accessible via a dam of rocky debris and soils crossing a side channel from the northern bank of the Nile. Islands like Kandi are surrounded by water all year round, even at the minimal water level of the Nile. They are absolutely dependent on rowing boats which transport people, animals, food and agricultural produce to and from the mainland. Farmers depend on trucks for transport between the villages and the city, as there are hardly any private vehicles in the region. The only axis of transport through the region alongside the Fourth Cataract is a track roughly parallel to the Nile which crosses a remote district characterised by maze-like rock formations. This might be one of the reasons for the political and economic isolation of the region.

Apart from the motorised, trans-regional transport, all regional transport is done using donkeys and to a much lesser extent camels along worn ‘camel-tracks’ (Plate 30).

### 6.2 The wild-growing vegetation in the study area

Vegetation along the Fourth Cataract is characterised by river oases and desert flora. The Nile, a river that carries water year round, crosses regions of extreme desert character. The banks of the Nile are covered in a lush, quite dense vegetation which changes to thinly covered briar and grass vegetation sharply without a transition zone. Thus, the wild-growing plant cover of the study area is restricted to the narrow flood plains of the Nile, the dry valley terraces and the waterless river valleys (*wadis*) of the adjacent desert. Two sharply differentiated vegetation units can be recognised.

*Plate 30. ‘Camel’ track in a palaeochannel.*

the river oases vegetation of the periodically flooded

Nile Valley plains
the xenomorphic desert vegetation of the valley terraces, *wadis* and sand dunes

While the water demand of the plant societies of the river plains is provided by the moist flood soils during flood seasons, the vegetation in the bordering extreme desert depends on the episodic, extremely low precipitations (< 50mm annually).

Habitats within the irrigated agricultural land, the palm groves and alongside the irrigation channels crossing desert areas have a special status. The water shortage is artificially overcome here so that plants from other vegetation units (river oasis, *wadi*) can establish themselves.

In light of the impending flooding of the Fourth Cataract by the Merowe Dam (now a reality), a comprehensive and scientifically-based documentation of the current wild-growing plant population is provided here.

It will be noted that vegetation may be negatively influenced by human use, pasture browsing (usually by donkeys and camels). It must also to be assumed the browsing by wild animal populations (rodents, desert foxes, gazelle etc.) plays a role.

### *6.2.1 Phytogeographic classification*[18]

The plants which can be found at the Fourth Cataract belong to the palaeotropic flora and are part of the Saharo-Sindic floristic region that encompasses the large arid area of the Sahara. The region is located within the great vegetation zone of deserts and semi-deserts of Africa, which is characterised by its relative poverty of species - 300 to 500 species have been proven to exist in the extreme deserts of the Sahara. The largest part of the Sahara by far is completely devoid of any vegetation; still it can be classified into inferior vegetation units by varying species composition due to climate, altitude and rocky ground. Thus, the floristic composition of the Fourth Cataract belongs to the superior *vegetation unit of the lower and intermediate position of eastern Sahara.* Another phytogeographical classification classifies the desert vegetation of the area as a part of the vegetation of the *Bayuda and central Nubian Desert.* A main characteristic of this sub unit are dry valleys (*wadis*) which predominate in areas of lower elevation in the Sahara and support abundant thorn shrubs and warmth-loving therophytes (after episodic rainfall). The plant populations on the flooded soils of the Nile Valley plains correspond to the *vegetation of oases, irrigation cultures and cultivation areas of the Nile Valley.* The bank slopes of the Nile, dominated by acacia trees, have not been classified as vegetation of deserts and semi-desert but have been matched with the superior vegetation unit of the savannah and precipitation-green dry forest zones due to their gallery forest-like formation.

Seven plant communities, or rather plant societies have been identified in the study area.[19]

### *6.2.2 The river-oases vegetation of the periodically flooded Nile Valley plains*

The wild-growing vegetation on the residual moisture that remains in the soils after the summer floods and in the higher bordering areas of the floodplains (Plate 31) is characterised by pronounced species richness. The higher banks are either not flooded or only during a short period of time, and produce a higher and denser tree vegetation in some parts. On the lower parts of the bank, the introduced river sediments, washed in by the flood, are preconditions for the fast colonisation of pioneer plants on the recent mud soils.

The colonisation areas of these plant societies are characterised by strong antipodes in flooding and moisturising during the flood season and desiccation with the occurrence of deep drought crevices (dessication polygons) in the ground during the dry season. However, the colonisation of plants is limited mainly to those habitats, where no cultivation of agricultural plants is taking place. Such habitats can thus be found especially along steep bank slopes and terraces near the river, on very rocky ground and on smaller, unused islands. These best reflect the native or at least undisturbed, wild-growing vegetation (cf. Figure 11).

*Plate 31. View over the Nile Valley floodplains near Dar el-Arab.*

Riparian fringes in floodplains, dominated by acacia trees

The tree and shrub vegetation at the bank slopes and terraces near the river, marking more or less the upper flooding limit in the flood season, is mainly dominated by acacias and tamarisks. Groundwater in reach of the roots is available all year round. Thus, the vegetation grows independent of precipitation events. Due to intensive land use in the form of irrigation, these habitats are mainly taken up by fields and date palm groves. Only on extremely steep or rocky riparian fringes can one still find sections of dense, floodplain-like acacia populations (Plate 32). Due to their savannah-like formation, these strongly frag-

[18] According to Knapp 1973.
[19] The classification of plant societies was done according to Knapp 1973.

Plate 32. Elements of gallery forests with Nile acacias.

mented elements of gallery forest can be classified as part of the plant society of **Acacia-Floodplain-Forests**. They mainly grow in thorny savannahs but also accompany the Nile in the extremely arid regions northwards into Egypt. Different acacia species mixed with tamarisks and dom palms are the main species of the society.

***Acacia nilotica*** is the typical species of the Nubian Nile Valley. With its large, expansive crown, it forms a noble tree which grows well on river banks with high ground water table and deep, sandy-loamy soils. Its foliage and florescence during the dry season points to the high ground water table it taps. Flooding can be survived without damage. Ignoring a few single individuals along irrigation channels, Nile Acacia only grows in the direct neighbourhood of the river. Its heavy wood is used in ship and tool construction, for posts and wood constructions for irrigation cultivation. Besides that it is used as fuel wood and to make charcoal. The leaves and seed pods are much liked by camels as fodder.

Another representative of the acacia-floodplain-forests is ***Acacia seyal*** (Seyal-Acacia). It usually colonises the higher bank areas in the second row behind the Nile acacias and furthermore grows along irrigation channels. If the floodplain-forest has already been destroyed by use, the Seyal-Acacia colonises the upper banks of the Nile floodplains in the form of shrubby stands. Its wood is also used as construction material and for fuel. Young shoots and leaves are fed to animals in times of need. Bark and leaves are still used in local medicine (for influenza, stomach problems and others) at times. In the more southern parts of the country, *Acacia seyal* (as a plantation tree) and *Acacia senegal* produce the globally exported gum arabic. It is unknown whether such a use is also implemented in the study area. It does not play any role as an economically important product however.

A valuable and the most diversely used tree species of this plant society is ***Acacia albida*** (Anatree), the largest acacia species of Sudan (Plate 33). Because of its high value for use, it can only be found very rarely or in the form of seedlings in the study area. It adapts well and is quite undemanding regarding the soil conditions; however, it needs groundwater in reach of its root system. Sporadically it also grows in cultivated land including palm groves where it is irrigated together with the other crops. Floods of several weeks duration are overcome without damage. Thus, the anatree also advances into the inundation areas of the Nile. Its light wood is used in carpentry and saddlery, for tools and in boat construction. Leaves and fruits play a role as nutritious camel fodder.

Plate 33. A single Acacia albida tree shortly before its cutting.

***Tamarix nilotica*** (Nile-Tamarisk) is a typical pioneer species which massively colonises the fresh mud-soils after the flood by re-sprouting and is common as tree and shrub vegetation in the acacia communities of the river banks and terraces. It forms thick, impenetrable populations of different growth forms and reaches heights of several metres. The trunks are used as fuel wood; the thicker ones are sawn into boards.

Sporadically, the acacia-floodplain-forests are interrupted by the palm crowns of ***Hyphaene thebaica*** (dom) which is a typical palm species of the Sahel and the borders of the Sahara (Plate 34). It is a characteristic component of river oases because it needs high groundwater levels and rich soils. The populations are quite well preserved in the study area because the species is diversely

Plate 34. Natural habitat of dom on valley terraces with high water table. A date palm plantations can be seen in the background.

used (cf. 6.1.1.5). It also grows in irrigation plots where it is both cultivated and naturally occuring.

Floodplain vegetation in the flooded Sectors of the Nile

After the retreat of the floodwaters from the Nile floodplains, pioneer vegetation will begin to settle on the moist and rich mud-soils. This plant society does not remain confined to the unused areas; it is composed of annual grasses, herbaceous plants, tamarisks and mimosas. The latter shrubs, whose shoots begin to regrow right after the flooding, often form massive populations and even partly advance into cultivation areas. The over-use of tamarisks and the destruction of mimosas often causes their retreat in favour of populations of *Desmostachya bibinnata*.

The vegetation has been classified as part of the society of the ***Tamarix nilotica (Tamarix gallica ssp. nilotica) – Woods***. There, **Tamarix nilotica** forms lower shrubs than in the strips of gallery forest and colonises especially the deeper mud-soils of the floodplains (Plate 35). Its deep root system permanently opens new colonies. In some parts, the sediments are accumulated that strongly and dune-like in these stands through the influence of wind that this species strongly influences morphology and the creation of sand banks and mud flats. Due to its fast reproduction rate and its positive effect as a wind-break, it is common in the floodplains. As a hapophile species it also colonises the dry flood-channels. Most of the lower shrubs are cut to provide wood.

*Plate 35. Young tamarisk shrubs in the Nile floodplains.*

Another common plant of the whole floodplain area is ***Mimosa pigra*** (Black Mimosa), an introduced thorny shrub from America. It mainly colonises very close to the river bank but it has also established itself as a nasty weed in the cultivation fields where it is fought mechanically.

***Desmostachya bibinnata*** grows in tall meadows on sites where tamarisks and mimosas have been strongly reduced (Plate 36). They often form thick populations on unused sites (like Magasir Island). It agricultural areas it is restricted to the borders of the fields or steep banks. There it is harvested or browsed. It often forms thick meadows along the dikes of irrigation channels. The leaves can be used to make rough ropes or as fodder.

A number of annual, herbaceous plants without anthropogenic use grow on steep banks or rocky ground. They put down roots into the washed in sediments after the flood. Besides several species of **Euphorbia** (e.g. *Euphorbia heterophylla*, *Phyllanthus niruri*, *Chrozophora plicata, Ricinus communis*), numerous species of **Fabaceae** (e.g. *Indigofera hochstetteri*, *Indigofera oblongifolia*, *Sesbania sesban*, *Tephrosia apollinea*, *Trigonella hamosa*) occur. Other species of this plant society include *Eclipta prostrata* (Asteraceae), *Echium longifolium* (Boraginaceae) and *Abutilon figarianum* (Malvaceae). Some of the listed species (e.g. *Ricinus communis*) are used in local medicine which shall not be commented upon further.

*Plate 36. Woman harvesting leaves of* Desmostachya bibinnata.

Different species of grasses intermingle in the moister sites, in irrigated land and alongside channels. Among the sweet grasses, ***Cynodon dactylon*** (bermuda grass) is definitely predominant. It can spread quickly and form dense meadows with its far reaching root system. It is known as a threatening weed in agricultural lands.

Sedges like ***Cyperus pustulatus*** and ***Cyperus pygmaeus*** also appear on wet soils, in depressions and near flood channels. Such salty, seasonally moist sites appear often due to the drainage of these water bodies. Consequently, tamarisks begin to colonise these sites or Fabaceae (Lupines, beans) are seeded.

The water and river vegetation

This plant community grows in the shallow waters of the Nile and in the immediate neighbourhood of the river banks. The loamy-clay soils are flooded during the inundation between July and September and for several months thereafter. During the low-water season, they are colonised by acid grasses, knot weed, mimosas and tamarisks, willows and reeds. The plants could not be classified clearly into one of the plant communities according to Knapp (1973). They are closely related to ***Tamarix nilotica (Tamarix gallica ssp. nilotica) – Woods***.

The riverbanks directly bordering the Nile and the areas of shallow water are dominated by another green strip of ***Cyperus pustulatus***, a species of cyperus. The plants grow in the water or form dense meadows on the wet mud-soils after the water recedes. Between rock cracks or on tiny

*Plate 37.* Cyperus pustulatus –
*habitatin a mud bank in the Nile.*

river islands where little sediment accumulates, *Cyperus pustulatus* often forms the only species.

***Mimosa pigra*** is another representative of this plant community, well adapted to flooding and strong currents. As a typical thorny shrub of the floodplains it occupies the river banks just above water levels in large numbers; however, mainly growing as single plants.

Use of the river banks has often pushed the populations to the rocky areas as on tiny islands and rock crevices. The whip-like shoots that always point in the direction of the current will often be found dead. However they are

*Plate 38. Shoreline shrub of* Mimosa pigra *(foreground)*
*and* Salix safsaf *(background).*

replaced by new shoots immediately after flooding. Black Mimosa is a pronounced pioneer, capable of stabilising washed-out sediments rapidly with its deep roots and thus contribute to the formation or enlargement of islands.

It sections of slow currents and in shallow, still waters in the Nile, ***Polygonum glabrum***, an aquatic knotweed flourishes. Its thin branches grow far out of the water. Even after the drying out of these sites, knotweed will continue to grow well on the mud-soils as long as they remain moist.

Willows – floodplain-shrubs with ***Salix safsaf*** (= *Salix subserata*) were formerly common inhabitants of the always moist banks with strong currents but today only

*Plate 39. Population of knotweed (*Polygonum glabrum*)*
*in a still and shallow part of the Nile.*

form isolated residual populations in the area due to heavy use. Shrubby individuals and narrow strips below elements of gallery forests were only encountered on the small, largely unused Nile islands (Figure 11). The willow switches are popular weaving material, therefore, larger stands do not exist in the area.

Like in all floodplains, ***Tamarix nilotica*** shrubs also colonise the freshly drained mud-soils near the banks. There they form low shrubs or young, single shoots which can develop less than in the higher bank areas due to the river currents and the long flooding period. The dense shrubs, therefore, rather form the second row behind the immediate river bank at the low-water-period.

***Cynodon dactylon*** and herbaceous plants like ***Jussiaea erecta*** or ***Ipomea spec.*** only partly advance into the extreme shore areas.

Reeds of ***Phragmites australis*** only occur along undisturbed shorelines like the steep banks of small islands (e.g. Magasir Island).

### *6.2.3 The xenomorphic desert vegetation of the valley terraces,* wadis *and sand dunes*

The desert region of the Bayuda and Nubian Desert which directly borders the river oasis of the Nile largely consists of vegetation free areas. Only the *wadis* and their tributaries, the dry terraces of the Nile Valley, the palaeochannels and in some parts the sand dunes harbour a sporadic but continuous vegetation carpet mainly consisting of thorny shrubs, medium and small shrubs and thin dry-land grasses. Their growth forms and species composition are mainly affected by exogenous factors like grazing, wood use and precipitation. The area-wise largest vegetation cover can be found in the currently hardly used *wadi*-beds of the hinterland which offer an open vegetation relatively rich in species. These extremely dry sites are exclusively dependent on water supply from the episodic rainfall which moisturise the soil for short periods on a few summer days. The limited water supply forces the

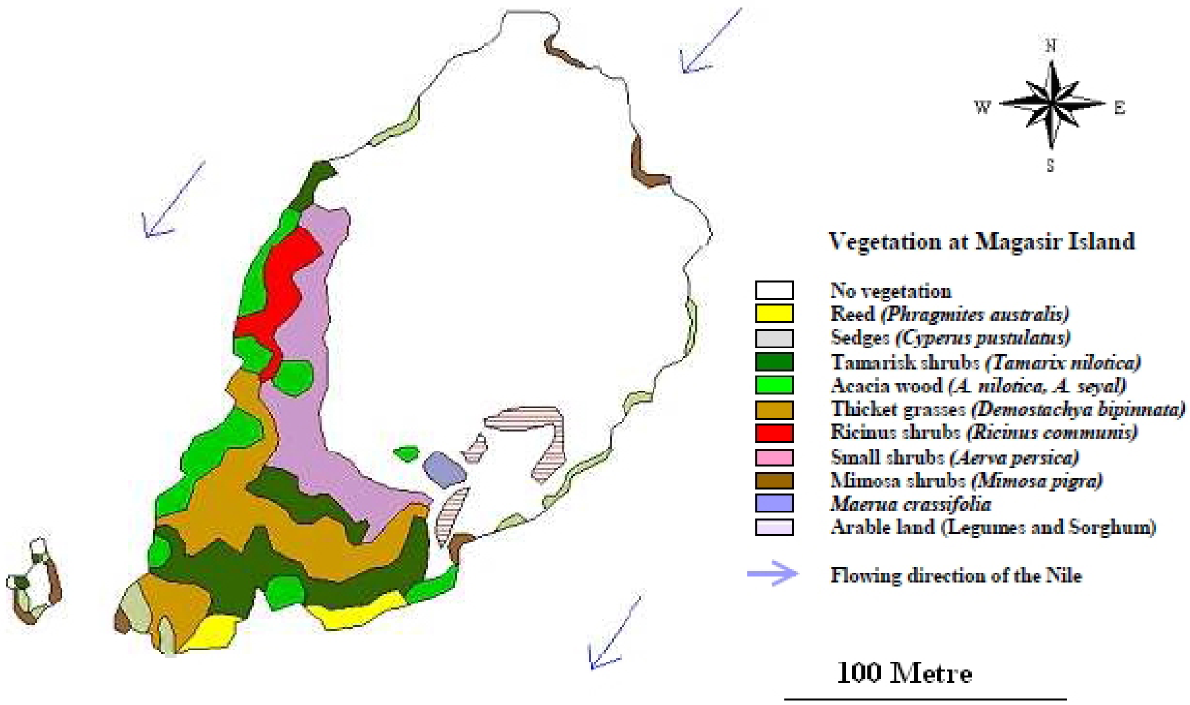


*Figure 11. Vegetation map. Largely natural river oases vegetation on Magasir Island. All three plant societies (see above) of the river oases vegetation are represented there.*

plants to grow widely spaced (root competition). On the terraces near the river, plant growth is supported by better groundwater conditions and accidental watering from the irrigation agriculture. However, the pressure from active use is much higher on those sites that in the *wadis*.

**Arid dry woods and dry-land grass vegetation of *wadi*-beds[201] and valley terraces**

The soils of *wadi*-beds with their sediment-rich and sandy-gravel layers and of dry valley terraces produce a light, open vegetation of brooms, acacia-woods, dry-land grasses and small shrubs. The plants usually grow widely spaced from each other (Plate 40). Grazing pressure and logging have negatively influenced the vegetation. Acacia trees for example are only left in small numbers and as single examples near settlements (*wadi* mouths and valley terraces).

The vegetation unit, dominated by shrubs, is part of the plant society of the ***acacia-woods in wadi-beds of the south-easterly Sahara.*** Of this society, largely undisturbed habitats with the highest vegetation density currently still occur in the remote *wadi* sections far from the settled Nile Valley. The acacia-woods form open, 3-4m high but mostly lower stands and are accompanied by other woody species, small shrubs and grass cushions.

A typical representative and the only tree species of the *wadis* is ***Acacia tortilis* ssp. *raddiana***, an umbrella acacia and a characteristic emblem of savannahs, the Sahel and Sahara margins (Plate 41).

*Plate 40. Light woody vegetation in a* wadi *bed (Wadi Um Keleit). The plateaux are completely devoid of vegetation.*

*Plate 41.* Acacia tortilis *ssp.* raddiana *surviving as a shade tree in a settlement area.*

It is known as an indicator of the limit of tree growth with regard to heat and drought and, like most desert plants, grows on its own and always at a great distances, one to another. It often colonises the *wadi*-beds at the base of the hills in order to benefit from the superficial drainage after a precipitation event. The trees are much liked by

[20] This also includes *wadis* if not used agriculturally

passing transport camels which still on occasion use the *wadis* as routes. The hard wood has an excellent energy value as fuel wood and for charcoal and also provides good construction material. The thorny branches are often used to fence in livestock. Larger umbrella acacias of 4-6m high can sporadically be found in settlements for giving shade while only smaller trees and shrubby forms dominate in the *wadis*. ***Acacia tortilis*** requires a ground water-root connection. Thus it marks the location of subterranean, irregular occurring water layers below the desert surface.

***Acacia ehrenbergiana***, forming a round shrub with its multi-stemmed shoots (Plate 42) is just as much a dominating and characteristic acacia species of this vegetation unit. It usually grows as single shrubs up to 3m in

*Plate 42.* Acacia ehrenbergiana*, typical thorn bush of arid habitats in the region.*

height on shallow, rocky gravel sites. It also grows well on open, unprotected sites where is accumulates aeolian sediments. It produces valuable fuel wood and has a high fodder value.

***Leptadenia pyrotechnica,*** a thorn and leafless broom, is one of the main species of the *wadi*-beds (Plate 43). It there forms the most common woody species with plentiful single shrubs of 1-3m in height. It likes sandy soils, particularly along the base of slope of sand dunes. It avoids rocky sites. Only thick-stemmed individuals are utilised for wood production – this probably explains its frequency. The "brooms" are used for broom (brush) production. The shrub attracts numerous insects with its yellow flowers; nonetheless, large parts of the shrubs are dried up during the drought season.

The most widely spread shrub species of the valley floor near the river and in *wadi* mouths is ***Capparis decidua***, a thorny caper (Plate 44). In contrast to the other solitary shrubs it often forms thick, continuous thickets and is the most apparent woody species in settlements and along paths and vehicle tracks. The leaves only appear during the rainy season or when there is a water supply from other sources (e.g. at the edges of irrigation plots and channels). ***Capparis decidua*** grows on loamy-clay soils, which explains its range near the river (terraces and palaeochannels). It rarely occurs in *wadis*. The awkwardly formed shrub grows in 2-3m high stands and accumulates dune

*Plate 43. Partly dried-up shrub of* Leptadenia pyrotechnica.

*Plate 44.* Capparis decidua – *shrub in a palaeochannel.*

sands around the stem shoots. The stems are normally too thin for wood use, thus it is utilised as a wind break and browsing source for donkeys or camels.

A tree species typical of the region and of diverse economic use can be found sporadically on valley terraces, in the area of *wadi* mouths and in planted form in settlements. It is ***Balanites aegyptiaca*** (Soapberry Tree); a species which has been cultivated in the middle and lower Nile Valley for 4000 years for its heavy wood but also for use in charcoal, oil and soap production. In spite of its economic importance and modesty in soil and water demands, only single individuals can be found at

*Plate 45.* Calotropis procera *in a* wadi-*bed.*

the Fourth Cataract. In contrast to plantations in the Sahel, they likely are the leftovers from an earlier period of use.

The lush green of ***Calotropis procera*** (Giant Milkweed) (Plate 45), a evergreen, woody shrub or tree with large, fleshy leaves, is unexpected on sandy desert sites, especially along the edges and in the middle of *wadi*-beds. Almost all parts of the tree are toxic, the plant is well protected against animal browsing which also explains its wide distribution in the region. Apart from that, it colonises the sites of other, grazed plants and quickly colonises degraded, unused soils (e.g. rubbish dumps) (Bebawi and Neugebohrn 1991) Although often regarded as a weed, the species is an important medicinal plant (soothing pain, asthma, arthritis) and an important supply of wood.

***Maerua crassifolia***, a typical tree species of semi deserts and thorny-shrub savannahs still grows in the region of the Fourth Cataract, but it requires water-supplied sites, which is why it occurs in large numbers mainly near the river, irrigation-areas and along channels. The very hard wood is used in tool-making and as fuel.

***Citrullus colocynthis*** (Colocynth), a ground-creeping pumpkin species which opens the sandy *wadi* soil with its long root sprouts, is part of the typical vegetation of *wadi*-beds (Plate 46). The bitter fruits are not edible, however they are used to treat malaria in local medicine.

*Plate 46*. Citrullus colocynthis *grows mainly in sandy* wadi-*beds.*

The grassy vegetation of *wadis* and valley terraces is almost exclusively made up of ***Panicum turgidum*** (Desert Grass), a dry-land grass up to 1.2m high. It is the species with the highest area cover in the *wadis* and is considered as one of the most important pasture grasses of the Sahara. During drought season it is often found dried up or heavily browsed so that only brush-like cushions remain. They are a characteristic element of the *wadis*.

The most common and most eye-catching semi shrub of the desert regions is ***Aerva persica*** (Plate 47). It colonises all desert habitats in isolation or in small groups, occurs in almost all *wadi*-beds including their tributaries and often grows extensively on unused agricultural land and alongside irrigation channels. The shoots are used as filling material for cushions or saddles. Furthermore it is used in the treatment of camel diseases.

A shrub which massively spreads under artificial irrigation is ***Cassia senna***. That is why it is strongly represented in settlement areas, especially along channels and field edges. The natural habitat of the legume is in the *wadis* and

*Plate 47. Dwarf-shrub of* Aerva persica *alongside a* wadi.

depressions of valley terraces where it regularly occurs. Leaves and pods serve for combating fevers.

***Pergularia tomentosa*** grows in sandy, shallow *wadi*-beds. It is a woody semi-shrub which dries up during the drought period. It is common in all of the Sahara but occurs less commonly in the study area.

**Small-Shrub societies of mainly rocky ground in the *wadis***

The rocky, shallow drainage channels of *wadis* are colonised by very open plant societies dominated by small shrubs (Figure 12). Acacias or other trees do not occur here. There plants belong to the '***Small-Shrub societies of the south-easterly Sahara on mainly rocky ground'*** vegetation/floristic unit and are adapted to extremely dry conditions. The small shrubs only sprout after a precipitation event and dry up relatively fast thereafter. Their habitats are the runlets of the lower hilly landscape which discharge into the *wadis* laterally (Plate 48). The *wadis*

*Plate 48. Thinly covered drainage channel in the area of a* wadi.

are formed by gravel and rocky debris. With increasing altitude, vegetation rapidly decreases and completely disappears near the headwaters.

A characteristic representative of this floristic unit is ***Fagonia cretica***, a woody, thorny, low shrub. It colonises the dry drainage channels in the higher boulder plateaux but also settles in the gravel-rock terrain of the *wadi*-beds. It is well protected against browsing by its sharp thorns,

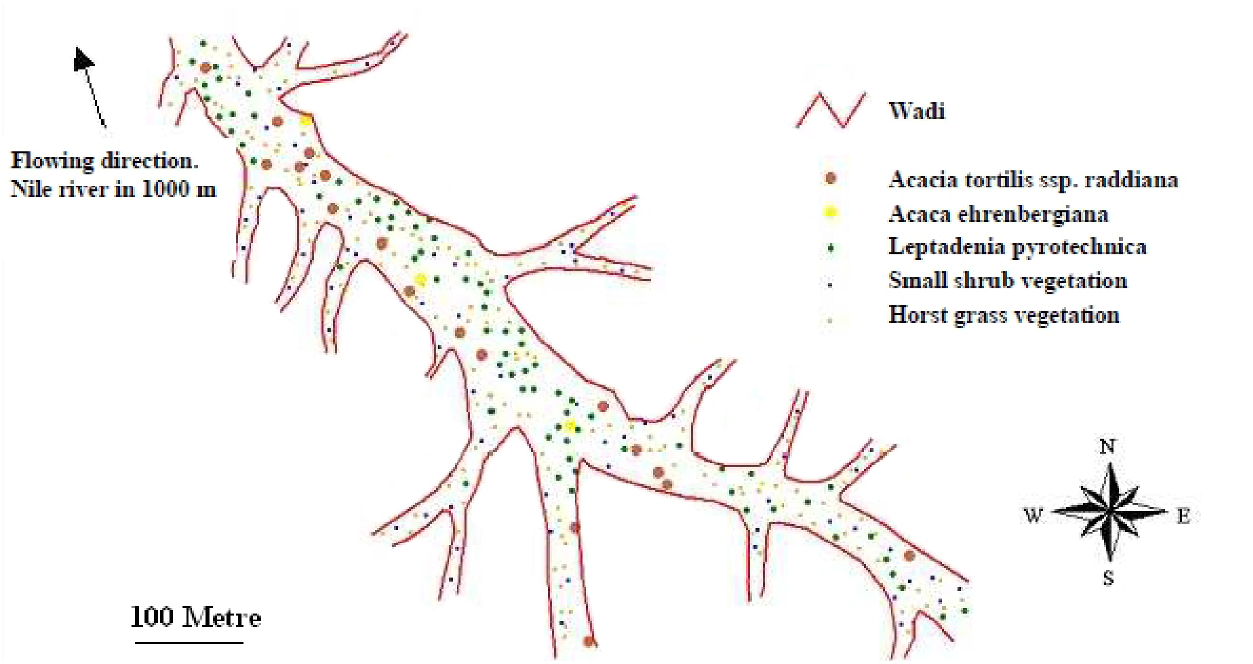


*Figure 12. Vegetation map: Largely natural vegetation in a* wadi*-bed (Wadi Um Keleit - Dar el-Arab) in the Bayuda Desert near the Fourth Cataract (cf. Figure 54). The vegetation is part of the plant society of Acacia-shrubs in* wadi*-beds of the south-eastern Sahara. In smaller catchments (drainage-channels), the vegetation changes over to that of Small-shrub societies of the south-easterly Sahara on mainly rocky plots.*

thus it also occurs abundantly in the settlement areas on the valley terraces. It is used as a medicinal plant against abscesses by the local population (Bebawi and Neugebohrn 1991).

Also, ***Panicum turgidum**, **Cassia senna*** and ***Aerva persica*** advance into these extreme habitats from the *wadi*-beds (Plate 49). At the time of the inventory in the dry season, most of there were already dried up but still, being quite noticeable, marked the course of the thinly colonized riverlets.

*Plate 49. A completely dried bunch of Panicum turgidum.*

Following the dried up riverlets towards the rock and boulder plateaux, only sparse vegetation could be found. Amongst it were ***Parietaria alsinaefolia,*** a low, rather herbaceous dwarf shrub which still flowered during the dry season, and ***Limeum indicum***, a creeping dwarf shrub.

Apart from the widely spread grass *Panicum turgidum,* two further grass species, although very sparsely represented, could be found (***Aristida plumosa*** and ***Aristida adscensionis***). Single plants of a thistle (***Atractylis sp.***) grew in the dry riverlets of the hinterland, far from the Nile.

**Vegetation of the drifting sands**

The vegetation of the drifting sands as its own plant society is quite uniform throughout the Sahara. It consists mainly of evergreen brooms. They are well adapted to being covered by drifting sands and they can fix dunes made up from loose, fine grained sediments. In the study area, blown-in dunes are quite common, especially on the northern Nile bank, where sediments from the Nubian Desert are blown in by the northerly trade winds. Most of the deserts in the region do not support vegetation. Only as an exception, ***Retama raetam*** can be found. It is a 2m high broom (Plate 50) that grows on exposed but lee-facing drifting sand dunes which cover rocky debris.

## 7. Summary

The primary intention of this study is to document comprehensively both the land use and the vegetation in an area along the Nile in the Fourth cataract, prior to the permanent inundation of the countryside. For this task, mapping of the vegetation, analysis and evaluation of air photographs and empirical studies of a part of the future reservoir were necessary.

The results show that the land use in the region of the Fourth Nile Cataract can be described as a form of a river oasis-economy run by families of small farm-

*Plate 50.* Retama raetam *at the foot of a sand dune which has been penetrated by rocky debris.*

ers. The subsistence-oriented cultivation of date palms, wheat, vegetables and legumes together with livestock breeding form the basis of livelihood for the Manasir and Shaiqiyya living there. A narrow river plain with dry rocky terraces as well as the dependence on diesel pump irrigation make intensive crop cultivation on a large scale impossible. Yet, the basic food supply can be secured due to the cultivation of a wide variety of crops and due to the fact that the river provides water all year long, which ensures cultivation, and constant yields, on the fertile soil of the river floodplain on small plots of land. Other forms of land use, such as fishery and forestry are based on traditional methods and form essential components of the people's economy. The settlements of the farmers are all located on the dry river terraces of the Nile and are built according to traditional mud-brick building methods. Aspects of an infrastructure such as roads and mains electricity do not exist.

The second part of this study focuses on the present wild growing vegetation in the area of the planned reservoir. The inventory of plants growing near the Fourth Cataract is characterised by the vegetation typical of river oases and deserts. Forty-nine species of plants were documented and were classified into five societies of plants. There were riverside woods of acacia and tamarisk shrubs in the Nile Valley as well as societies of acacia and small shrubbery in the *wadi* beds.

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# Appendix A: Interview guidelines on current land use at the Fourth Cataract

The interviews took place in January 2003 and January 2004 with farmers in Dar el-Arab (especially Mohammed Ahmed el-Ajami).

1. **Agriculture**

- Which crops grown there and what are the periods during which they grow?
- What habitat requirements have these cultures?
- How does the growing spectrum of the Nile plains differs from the irrigation land?
- What is a typical crop rotation?
- What are the planting and harvesting dates of crops?
- How are the crops used?
- Are plant protection and fertilization measures in operation?
- What management methods are used?
- How is the ownership organised?
- What are the relationships to a market?
- How was the development of agriculture in the area?
- What is the food supply for the animals?

2. **Fishery**

- How many species of fish are caught?
- Is fishing profitable?

3. **Use of wood and raw materials**

- What raw materials are used in the area?

- How are they used?

# Appendix B: Culture plant species at the Fourth Cataract

| English name | Botanical name | Plant family | Synonyms | |
|---|---|---|---|---|
| | | | Arabic | German |
| | | | | |
| **Cereals** | | | | |
| Pearl millet | *Pennisetum glaucum* | *Poaceae* | Duchun | Perlhirse |
| Sorghum | *Sorghum bicolor* | *Poaceae* | Durra, Sorghum | Hirse |
| Wheat | *Triticum aestivum* | *Poaceae* | Gemeh | Weizen |
| | | | | |
| **Fruits** | | | | |
| Banana | *Musa spec.* | *Musaceae* | | Bananen |
| Date Palm | *Phoenix dactylifera* | *Arecaceae* | Balah | Dattelpalme |
| Dom Palm | *Hyphaene thebaica* | *Hyphaene* | Dom | Dom Palme |
| Guava | *Psidium guajava* | *Myrtaceae* | Gawafa | Guaven |
| Mango | *Mangifera indica* | *Anacardiaceae* | Manga | Mango |
| Orange | *Citrus sinensis* | *Rutaceae* | Bortugaal | Orange |
| Zitronen | *Citrus limonum* | *Rutaceae* | Laimun | Lemon |
| | | | | |
| **Legumes** | | | | |
| Cow Pea | *Vigna unguiculata* | *Fabaceae* | Luba | Kuhbohne |
| Horse Bean | *Vigna faba* | *Fabaceae* | Foul | Ackerbohne |
| Congo Pea | *Cajanus cajan* | *Fabaceae* | Adis | Straucherbsen |
| Egyptian Lupin | *Lupinus termis* | *Fabaceae* | Turmus | Weiße Lupinen |
| | | | | |
| **Vegetables** | | | | |
| Aubergine | *Solanum melongena* | *Solanaceae* | Aswad | Aubergine |
| Cucumber | *Cucumis sativus* | *Cucurbitaceae* | Himaid | Gurken |
| Ocra (Ladies fingers) | *Abelmoschus esculentus* | *Malvaceae* | Bahmia | Okra |
| Sweet Pepper | *Capsicum annum* | *Solanaceae* | Filfil | Paprika |
| Rucola | *Eruca sativa* | *Cruciferae* | Girgeer | Rucola |
| Sweet potato | *Ipomoea batatas* | *Convolvulaceae* | Batates | Süsskartoffeln |
| Tomato | *Solanum lycopersicum* | *Solanaceae* | Tamatim | Tomaten |
| Onion | *Allium cepa* | *Allioideae* | Basal | Zwiebel |
| | | | | |
| **Spices** | | | | |
| Basil | *Ocimum basilicum* | *Lamiaceae* | Rihaan | Basilikum |
| Fenugreek | *Trigonella foenum-graecum* | *Fabaceae* | Helba | Bockshornklee |
| Chili | *Capsicum spec* | *Solanaceae* | Shatta | Chilischoten |
| Sweet cumin | *Foeniculum vulgare* | *Apiaceae* | Shamaar | Fenchel |
| Hibiscus | *Hibiscus sabdariffa* | *Malvaceae* | Karkade | Hibiscus |
| Coriander | *Coriandrum sativum* | *Apiaceae* | Kusbarah | Koriander |
| | | | | |
| **Fodder plants** | | | | |
| Egyptian Clover | *Trifolium alexandrinum* | *Fabaceae* | Barsim | Alexandriner Klee |
| Clover | *Medicago sativa* | *Fabaceae* | Barsim | Luzerne |
| | | | | |
| **Trees** | | | | |
| Niem | *Melia indica* | Meliacea | Neem | Niembaum |
| Soapberry | *Balanites aegyptiaca* | *Sapindaceae* | Lalob | Seifenbeerenbaum |

# Appendix C: Wild-growing Vegetation at the Fourth Cataract

| Botanical name | Family | Synonyms (Arabic/German/ English) | | |
|---|---|---|---|---|
| **Trees and shrubs** | | | | |
| *Acacia albida* | *Mimosaceae* | Haraz | Anabaum | Ana Tree |
| *Acacia ehrenbergiana* | *Mimosaceae* | Salam | | |
| *Acacia nilotica* | *Mimosaceae* | Sunt, Garad | Nil-Akazie | Nile acacia |
| *Acacia tortilis ssp. radiana* | *Mimosaceae* | Samuur | Schirmakazie | Umbrella acacia |
| *Acacia Seyal* | *Mimosaceae* | Taleh | | |
| *Balanites aegyptiaca* | *Balanitaceae* | Lalob | Wüstendattel, Seifenbeerenbaum | Soapberry |
| *Capparis decidua* | *Capparidaceae* | Tundub | Kappernstrauch | |
| *Calotropis procera* | *Asclepiadaceae* | Ushar | | Giant Milkweed, Rubber tree |
| *Leptadenia pyrotechnica* | *Asclepiadaceae* | Mariach | | |
| *Maerua crassifolia* | *Capparidaceae* | Sarha, Sareh | | |
| *Melia indica* | *Meliacea* | Neem | Niembaum | Neem tree |
| *Mimosa pigra* | *Mimosaceae* | Shagrt el-Fas | Schwarze Mimose | Catclaw Mimosa |
| *Retama raetam* | *Papilionaceae* | | Rutenginster | |
| *Sesbania sesban* | *Papilionaceae* | | Saisabaan | |
| *Salix safsaf* | Salicaceae | Safsaf | | |
| *Tamarix nilotica* | *Tamaricaceae* | Tarfa | Nil-Tamariske | Tamarisk |
| *Ziziphus spina-christi* | *Rhamnaceae* | Sidir, Nabag | Christusdorn | Christ Thorn |
| **Herbs** | | | | |
| ***Abutilon figarianum*** | *Malvaceae* | Gargadaan | | |
| ***Aerva persica*** | *Amaranthaceae* | Areia, Ghubeisch, Ras esh-Shaib | | |
| ***Bergia odorata*** | *Elatinaceae* | Mermit | Tännel | |
| ***Cassia senna*** | *Caesalpiniaceae* | Sennamaka | | Alexandrian Senna |
| ***Citrullus colocynthis*** | *Cucurbitaceae* | Handal | Koloquinte | Bitter Apple |
| ***Cucumis sativus*** | *Cucurbitaceae* | Himaid, Gurke | | |
| ***Cistanche philypaea*** | *Orobanchaceae* | Halook | | |
| ***Datura stramonium*** | *Solanaceae* | | Sakaran Gemeiner Stechapfel | Thornapple, Jimson Weed |
| ***Echium longifolium*** | *Boraginaceae* | Kahali, Shok el-Gimal | | |
| ***Eclipta prostrata*** | *Compositaea* | Tamr el-Ganam | | |
| ***Euphorbia heterophylla*** | *Euphorbiaceae* | | Bechertragende Wolfsmilch | Mexican Fire Plant |
| ***Fagonia cretica*** | *Zygophyllaceae* | Abu Shoeweika, Abu Shoka | | |
| ***Glinus lotoides*** | *Molluginaceae* | Rabaat el-Bahr | | |
| ***Indigofera hochstetteri*** | *Papilionaceae* | Sharaya | | |
| ***Indigofera oblongifolia*** | *Papilionaceae* | Dahasir | | |
| ***Jussiaea erecta*** | *Onagraceae* | Aroos el-Bahr | | |
| ***Limeum indicum*** | *Molluginaceae* | | | |
| ***Paritaria alsinaefolia*** | *Urticaceae* | | | |
| ***Pergularia tomentosa*** | *Asclpiadaceae* | | | |
| ***Polygonum glabrum*** | *Polygonaceae* | Timsahiya | | |
| ***Pulicaria undulata*** | *Asteraceae* | | | |
| ***Ricinus communis*** | *Euphorbiaceae* | Khirwih | | Castor Oil Plant, Castor Bean |
| ***Striga hermonthica*** | *Scrophulariaceaa* | El-Wail, Budda, | | Witchweed |
| ***Tephrosia appollinea*** | *Papilionaceae* | Amujoga | | |
| **Grasses** | | | | |
| ***Aristida plumosa*** | *Poaceae* | | | |
| ***Aristida adscensionis*** | *Poaceae* | Homra | Gaaw | |
| ***Cynodon dactylon*** | *Poaceae* | Nejeel, Hundszahn, Bermuda Grass | | |
| ***Cyperus pustulatus*** | *Cyperaceae* | | | |
| ***Cyperus pygmeus*** | *Poaceae* | Kilaywat | Elattoot | |

| Botanical name | Family | Synonyms (Arabic/German/ English) | | |
|---|---|---|---|---|
| **Grasses** | | | | |
| ***Desmostachy bibinnata*** | *Poaceae* | Halfa | Halfa Gras | |
| ***Panicum turgidum*** | *Poaceae* | Tumaan | | |
| ***Phragmites australis*** | *Poaceae* | Boos, Gana | Gewöhnliches Schilf | Common Reed |

# Appendix D: Wild-growing vegetation at the Fourth Cataract arranged by habitat

| | **The river-oases vegetation of the periodically flooded Nile Valley plains** | **The xenomorphic desert vegetation of the valley terraces, *wadis* and sand dunes** |
|---|---|---|
| **Trees and shrubs** | *Acacia albida*<br>*Acacia nilotica*<br>*Acacia seyal*<br>*Maerua crassifolia*<br>*Mimosa pigra*<br>*Mimosa pigra*<br>*Salix safsaf*<br>*Tamarix nilotica*<br>*Tamarix nilotica* | *Acacia ehrenbergiana*<br>*Acacia tortilis ssp. radiana*<br>*Balanites aegyptiaca*<br>*Calotropis procera*<br>*Capparis decidua*<br>*Leptadenia pyrotechnica*<br>*Retama raetam*<br>*Ziziphus spina-christi* |
| **Herbs** | *Abutilon figarianum*<br>*Cassia senna*<br>*Crozophora placata*<br>*Cucumis sativus*<br>*Datura stramonium*<br>*Echium longifolium*<br>*Eclipta prostrata*<br>*Eruca sativa*<br>*Euphorbia heterophylla*<br>*Glinus lotoides*<br>*Indigofera hochstetteri*<br>*Indigofera oblongifolia*<br>*Jussiaea erecta*<br>*Phyllantus niruri*<br>*Polygonum glabrum*<br>*Pulicaria ondulata*<br>*Pulicaria undulata*<br>*Ricinus communis*<br>*Sesbania sesban*<br>*Striga hermonthica*<br>*Tephrosia appollinea* | *Aerva persica*<br>*Bergia odorata*<br>*Cassia senna*<br>*Cistanche philypaea*<br>*Citrullus colocynthis*<br>*Fagonia cretica*<br>*Limeum indicum*<br>*Paritaria alsinaefolia*<br>*Pergola tormentosa* |
| **Grasses** | *Cynodon dactylon*<br>*Cyperus pustulatus*<br>*Cyperus pygmeus*<br>*Desmostachy bibinnata*<br>*Phragmites australis* | *Aristida adscensionis*<br>*Aristida plumosa*<br>*Panicum turgidum* |

# Appendix E: Wild-growing vegetation at the Fourth Cataract ordered by plant societies

| **Vegetation unit** | **Flussoasenvegetation der periodisch überschwemmten Niltalaue** | | | **Wüstenvegetation der Talterrassen, Wadis und Sanddünen** | | |
|---|---|---|---|---|---|---|
| **Plant communities** (author's designation) | Riparian fringes in flood plains, dominated by acacia woods | Floodplain vegetation in the flooded sectors of the Nile | The water and river vegetation | Arid dry woods and horstgrass vegetation of *wadi*-beds[1] and valley terraces | Small-shrub societies of mainly rocky ground in the *wadis* | Vegetation of the drifting sands |
| **Plant societies** Knapp (1973) | Flood plains and gallery woods of savannah regions | Tamarisk shrubs of Sahara | Tamarisk shrubs of Sahara | Open acacia shrubs of Sahara and similar societies | Open small-shrub vegetation on rocky ground | Vegetation of the drifting sands |
| **Subordinate plant societies** Knapp (1973) | Acacia-floodplain-woods of thorn savannahs | Tamarix nilotica (= Tamarix gallica ssp. nilotica) – Shrubs | Tamarix nilotica (= Tamarix gallica ssp. nilotica) – Shrubs | Acacia-shrubs in *wadi*-beds of the south-east Sahara | Small-shrub societies of the south-east Sahara | Vegetation of the drifting sands |
| **Dominant species** | *Acacia nilotica*<br>*Acacia albida*<br>*Acacia seyal*<br>*Hyphaene thebaica*<br>*Tamarix nilotica* | *Tamarix nilotica*<br>*Mimosa pigra*<br>*Desmostachya bibinnata*<br>*Ricinus communis*<br>*Jussiaea erecta*<br>*Eclipta prostrata*<br>*Euphorbia heterophylla*<br>*Indigofera oblonga*<br>*Indigofera hochstetteri*<br>*Glinus lotoides*<br>*Echium longifolium*<br>*Abutilon figarianum*<br>*Tephrosia appollinea* | *Cyperus pustulatus*<br>*Cyperus pygmeus*<br>*Polygonum glabrum*<br>*Mimosa pigra*<br>*Salix safsaf*<br>*Phragmites australis* | *Leptadenia pyrotechnica*<br>*Acacia ehrenbergiana*<br>*Acacia tortilis* ssp. *radiana*<br>*Balanites aegyptiaca*<br>*Panicum turgidum*<br>*Aerva persica*<br>*Fagonica cretica*<br>*Cassia senna*<br>*Capparis decidua*<br>*Callotropis procera*<br>*Maerua crassifolia* | *Aerva persica*<br>*Fagonia cretica*<br>*Cassia senna*<br>*Citrullus colocynthis*<br>*Panicum turgidum*<br>*Limeum indicum*<br>*Paritaria alsinaefolia*<br>*Pergola tormentosa*<br>*Aristida plumosa*<br>*Aristida adscensionis* | *Retama raetam* |