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SUDAN NATIONAL ENERGY ASSESSMENT
FORESTRY AND WOODFUEL RESOURCES

NATIONAL ENERGY ADMINISTRATION
MINISTRY OF ENERGY AND MINING

and

FORESTRY ADMINISTRATION
MINISTRY OF AGRICULTURE AND IRRIGATION

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1.0 Introduction

Sudan is a vast country, the largest in Africa. It covers over 2.5 million square kilometers and extends from latitude 4° to 22° north and longitude 26°-36° east. Therefore, Sudan encompasses many ecological zones characterized by a variety of vegetation. This, coupled with a very weak modern infrastructure, makes quantification of Sudan forestry resources extremely difficult. Normal methods for estimating a country's growing stock, such as extensive aerial photography and ground reconnaissance are both expensive and presently beyond the means of the Forestry Administration.

Therefore, at an early date during the first phase of the Sudan National Energy Policy and Planning Project, NEA staff working with the Forestry Administration chose to adopt the following strategy for obtaining rough estimates of Sudan's current forestry resources.

First, the Head of the Forestry Administration's Inventory Section, Sayed Mohammed Hannafi Obeid, was sent by the project to the Nairobi Regional Remote Sensing Facility (March and April, 1982) to work closely with their staff to draw up a complete vegetation map of Sudan. LANDSAT imagery covering Sudan from 1972 up to 1979 (with the bulk of the imagery covering 1972-73) were utilized in identifying thirteen (13) different vegetation strata. Each stratum represented a similar density type vegetation and not an ecological zone or class.
Besides the 13 strata there were forest plantations. As most plantations could not be detected on the LANDSAT images they were collected from existing plantation records. The area north of latitude 14°N was not classified into different density types of vegetation since vegetation beyond this limit is too sparce and scarce to be detected on LANDSAT images. It consists mainly of semi-desert and desert type vegetation. LANDSAT coverage for this period was not entirely continuous, there were gaps in seasonal coverage and many areas were covered by only one or several photographs for the years 1972-1979. Further weaknesses in the data derived from the fact that many of the areas covered, particularly in central and eastern Sudan, had changed dramatically (primarily due to mechanized agriculture) in the period from 1972/1973 to the present.

Second, use of LANDSAT imagery was coupled with a systematic examination of available aerial photographs (mostly from the 1960s) and numerous Forestry Administration studies (e.g. saw mill operations) and management plans (primarily for Blue Nile Province), as well as forestry studies conducted in other areas of the country. Such groups as the British ODA (Imatong Mountains in the south), Hunting Services (South Kordofan, and Jebel Marra in Darfur), GTZ (Nuba Mountains, South Kordofan), the joint Jonglei Province (Southern Region), and other groups provided fairly extensive information that complemented and added to information obtained through LANDSAT materials.

Finally, after studying Sayed Hannafi's LANDSAT vegetation profile, the project

decided to send teams to several provinces of central and eastern Sudan to conduct limited ground surveying and enumeration. The purpose of these field visits was to update, as far as possible, estimates derived from other sources. It was known that forestry resources in these provinces (Blue Nile, White Nile and Kassala) had been most drastically affected (primarily through mechanized agriculture and charcoal production) over the past decade. Two teams, comprised of foresters and botanists, covered these areas. One team surveyed from Damazin to Kurmuk in the western and southern areas of Blue Nile and into White Nile Province, while the other team surveyed eastern White Nile and southern Kassala from the Dinder game reserve (along the Ethiopian border) to Gedaref. Between the two teams, several hundred trees, representing mostly native species in the areas surveyed, were felled and measured. A more detailed description of this methodology follows.

2. Methodology

Satellite imagery interpretation

The method used was visual interpretation of multi-spectral satellite (LANDSAT) images . Colored composite images were used. These generally showed vegetation as a very deep and intensely red color during the wet season while during the dry season images showed differing amounts of reddishness depending on the amount of chlorophyll in the plant cells. Dry season images often showed areas of extensive fires (dark in tone). The criteria used as a basis for stratification were as follows:

(a) The degree of red color is an indication of the amount of foilage and green leaf-cover. A very intense, deep red color image existing through the year indicates an evergreen tree species. Such scenes were identified as belonging to stratum ONE, which is "closed canopy forest associated with mountain areas".

(b) Another guiding criterion was the extent of burning that takes place during the dry season. The area of annual fires is an indicator of the openness, or forest crown cover. The extent of annual fires and the frequency of their occurrence is a good guide to the stratification of forest areas.

A number of images at different times of the year were carefully examined before delineating the boundaries of the different strata.

The images used included all those that were available in the Nairobi Remote Sensing Facility. On average, four scenes were viewed before selecting the best one for drawing the strata boundaries. The area most closely examined extended from latitude 14°N to the southern edge of the country (approximately latitude 4°N). Each scene covered an area of about 34,000 km^2 of 185 x 185 km on a scale of 1:1,000,000. Thirteen (13) strata and one sub-stratum plantation were defined. These were classified as follows:

Stratum 1: closed canop. forest areas with multi-story evergreen vegetation usually associated with mountainous areas. The color of the scene is a very intense, deep red during the wet season. During the dry season, the red tone is also visible. This

has been taken to indicate a crown cover of 80-100%. These areas are usually found at high altitudes ranging between 1,500-3,000 meters above sea level. In these areas, rainfall is generally high (the highest in Sudan), reaching annually between 1,500mm - 2,400mm. This stratum includes the Imatong and Dongotona mountains in the Southern Region.

Stratum 2: also associated with mountainous areas but shows lower crown coverage of between 70-80%. The scene during the wet season is usually very red in color. It also shows red tone during the dry season indicating an evergreen forest cover and a multi-story forest formation.

Stratum 3: the wet season scene is usually reddish-brown in color during the wet season. During the dry season, the scene shows a small degree of fire occurring annually, indicated by black colored areas in each scene. This has a crown cover of 50-70%. It includes, for the most part, high rainfall savannah woodlands. This type of vegetation is particularly characteristic of the ironstone region and occupies most of Bahr el Ghazal and Western Equatoria Provinces in the south.

Stratum 4: images show brown colors during the wet season. During the dry season there is a moderate degree of fire occurrence. This area is considered to have a crown cover ranging between 40-50%. This is broad leaf savannah woodland with a rainfall above 800mm.

Stratum 5: images show light brown tone colored scenes during the wet season and a high degree of fire occurrence during the dry season. This stratum indicates crown cover of 30-40% and is usually found in low rainfall woodland and savannah, including both low rainfall woddland savannah on sandy plains and the clay plains of savannah woodland with up to 600mm of annual rainfall.

Stratum 6: very deep brown tone colored images during the wet season and a high degree of fire occurrence during the dry season characterize this stratum. The forest crown cover is considered to occupy less than 30% of the total area of each scene. This has been stratified as bushland with low rainfall savannah woodland including both sandy plains and clay plains with up to 400mm of annual rainfall.

Stratum 7: consists of scenes which have a red tone during the wet season. During the dry season most of the area is subject to fires leading to large patches of dark colored areas on satellite images. However, areas along water courses are red in color during the dry seasons. These are classified as riparian forests along rivers and drainage courses (e.g. khors/arroyos).

Stratum 8: scenes are deep red during the wet season. During the dry season most of the area continues to show this reddish tone. This indicates a persistence of green foilage throughout the year and has been classified as swampy vegetation.

Stratum 9: deep red in tone with a regular pattern of irrigation canals and service roads which are easily recognized on LANDSAT images. This stratum is classified as irrigated agricultural land (comprising over 3 million feddans of the area studied).

Stratum 10: shows scenes which are deep red during the wet season, with large, square systematic patterns. The images usually have a black tone during the dry season indicating the annual occurrence of fires. This stratum is classified as dry land mechanized farming.

Stratum 11: characterized by scenes which are deep red in color during the wet season and which have irregular shapes. During dry seasons most of the area is burned by fires. This stratum has been classified as the shifting cultivation zone.

Stratum 12: typified by scenes which are deep red in color during the wet season. During the dry season most of the area is covered by fires and is classified as tall grassland.

Stratum 13: areas that are deep red in color during the wet season and show considerable burning during the dry season, but also show patches of reddish tone. This stratum has been classified as tall grassland with scattered trees.

Table 1

stratum	definition/description
1	Closed canopy montane forests: appears very deep red on LANDSAT images. Associated with highlands, hills and mountains. 80-100% crown cover.
2	Nearly-closed montane forests: appears red on LANDSAT images. Associated with highlands. 60-80% crown cover.
3	High rainfall savannah forests: appears reddish brown on LANDSAT images. In area of 900-1,000mm annual rainfall. 50-60% crown cover.
4	Savannah woodlands: annual rainfall between 600 and 950mm. 40-50% crown cover.
5	Low-rainfall savannah woodland: annual rainfall between 400 and 600mm. 30-40% crown cover.
6	Bushlands: annual rainfall approximately 400mm. Greater than 30% crown cover.
7	Riverian forests: found along river drainage areas, "khors" and rivers. Generally not continuous, diffused.
8	Swampy vegetation: found in large swampy areas with poor drainage, frequently standing water. Trees very water-tolerant.
9	Irrigated agricultural land
10	Mechanized rainfed agricultural land: characterized by very symmetrical patterns.
11	Shifting cultivation land: irregular shapes, changing from year to year.

12 Tall grassland

13 Grass with trees: sparse vegetation usually scattered over areas of rough contours.

14 Forestry Administration plantations: Acacia Nilotica and Eucalyptus spp.

2.1. Aerial photography and existing studies

It must be remarked that LANDSAT images used by themselves do not reflect the volume of forests nor species composition. The only way to determine the actual composition and true volume of the existing forest cover is through ground surveillance. However, groundwork is very time-consuming and expensive, therefore an extensive, proper forest inventory was not possible. Available aerial photographs can be (and were) used in different forms to render forest inventory more economically feasible and LANDSAT imagery provided an available tool for making initial inventory estimates. As stated above, this technique was complemented by the use of available aerial photographs and limited ground reconnaissance. For many years, the only available data on forest resources for the Sudan were the preliminary rough estimates carried out by J.K. Jackson for the Food and Agricultural Organization of the United Nations in 1960. According to Jackson's estimates out of the 2.5 million km^2 of the total surface of the Sudan, productive forested areas were assumed to cover a 55 thousand km^2 (18% of total area) with related total volume (or growing stock) of 1300 million m^3 and annual allowable cut of nearly 200 million m^3. The total wood volume consisted to a large extent of fuelwood and sawn timber resources and to a lesser extent of building poles, gum arabic and dom nuts.

Jackson stated that the study was a rough estimate of forest resources of the Sudan, since no adequate data were available at the time for a sound estimate. Many of the figures used in the report were merely guesswork with a margin of even as high as 50%. As an example, Jackson assumed an annual yield of sawn timber from all potential accessible resources in the Sudan of 154,750m^3/year (17,200m^3/year for northern Sudan and 137,550m^3 for southern Sudan).

His estimates were based on two rough methods for estimating annual yield (Brandis' and Von Mantel's formula) which seemed justifiable at the time because of the unreliability of the available data on growing stock.

The Brandis' method defines the yield as the ratio of the volume produced by the trees over the girth limit to the time taken to replace growing stock, called the cutting cycle. In a case where the growing stock is known, Von Mantel's method defines the yield as the ratio of total growing stock to half the rotation. Recent small-scale inventories carried out in the Imatong Mountains by ODA, the Jebel Marra region by Huntings, Bahr el-Ghazal region by the Forestry Administration (for saw mills) and the managed forests specifically in Blue Nile region, have clearly shown that the assumptions used in these two methods are not valid today (high yield figures and low cutting cycles).

According to a recent FAO report, industrial and non-industrial plantations were estimated to cover over 185,000 ha (1980). Industrial hardwood species which cover

about 55 thousand ha include Acacia nilotica, Cedrella toona, Cardia africana, Khaya grandifoliola and Tectona grandis. These species are a source of firewood, sawn timber (sleeper) and supply a particle-board factory from the "green belt" established south of Khartoum. Industrial softwood species estimated to cover 2.7 thousand hectares consist mostly of Cupressu species. Non-industrial plantations consist chiefly of hardwood species (Acacia spp., Azadirachta indica, Cassia siamea, Eucalyptus spp., Hyphaene thebaica and Prosopis chilensis. These species, which cover about 130 thousand ha, are grown for the production of gum arabic, charcoal and firewood, and for the establishment of shelter belts.

In an attempt to determine the annual amount of forest volume lost due to fire, shifting cultivation and fuelwood and pole consumption, Hasek estimated this amount to approach 20 million m^3/year (1956 FAO report).

In a 1978 study for the Forestry Administration, Mohammed El-Amin Mukhtar estimated forest resources to cover about 586 thousand km^2 or 23% of the total area of the country, with a total growing stock volume of 1,355 million m^3 and an estimated mean annual allowable cut of 67.75 million m^3 (assumed mean annual increment of 5% for the entire growing stock), and mean wood density of 0.33 metric tonne/m^3. This amount is subject to losses caused by fire, drought spells and mechanized agriculture totalling 4.8 million m^3. In addition an estimated 8 million m^3 of moderate to high quality wood is used annually for timber manufacturing (sawn timber, round timber and poles), resulting in a net annual allowable cut of 55 million m^3, mostly dedicated to fuelwood use, which is estimated at 42.6 million m^3.

It must be pointed out, however, that these limited studies, when compared with current estimates, reveal extensive and alarming degradation of natural vegetation in the central and eastern regions of the country, the time and extent of which cannot be systematically and scientifically determined without detailed study.

2.2. Ground sampling

Based upon LANDSAT and the surveys mentioned above, a ground sampling framework was established whereby local, unpaved routes were trekked by two teams of foresters and botanists. The time allowed for these surveys was limited by the project time-table and the imminence of the rainy season. Altogether, eight team weeks (during a five week period) were spent in the field conducting ground surveys.

In the southern area of Blue Nile Province, sample plots were systematically located two to each side of the route every 30 kilometers along the route. Teams walked one kilometer on either side of the road away from villages and cultivated areas. Sample plots measured 4 hectares (200 by 200 meters). Every tree greater than eight centimeters in diameter was measured at breast height. Instruments used included callipers, diameter-tapes, ranging poles, survey chains and prismatic compasses. Plots were also studied to obtain information on soil, water drainage, undergrowth and accessibility. The teams selected trees considered of potential commercial value to save both time and manpower. These trees were felled and measurements taken at the bottom, the middle and seven centimeters from the top.

When areas of human habitation or shifting cultivation were encountered at the

30 kilometer measuring points, the team selected sites adjacent to but away from these areas. However, in areas cleared for mechanized farming, the teams reported tree coverage as zero.

In other parts of Blue Nile Province the team followed much the same procedure but reduced the area of each survey plot to 0.5 hectares (100 meters by 50 meters). The reason for reducing the size of the plots was a far greater human impact on the vegetation and a desire to more closely examine existing natural cover. Again, plots were laid on either side of the routes one kilometer away from the roads. Diameter measurement classes were reduced from 4cm to 2cm to better record the volume. In the central and northern parts of Blue Nile some 32 samples were laid out, with 15 showing virtually no native forests or trees (due, primarily, to cutting for mechanized agriculture).

In White Nile Province, 11 sample plots were laid out using the same techniques applied in the central and northern areas of Blue Nile Province. Out of this total only one plot was reported as cleared of all natural forest vegetation.

Thirty sample plots were taken in Kassala Province using the same methodology used in central and northern Blue Nile. Out of this total, 21, or over two-thirds of the plots surveyed, were devoid of natural tree vegetation. The remaining nine showed significantly lower vegetation cover and tree volume than had ever been estimated by the Forestry Administration. Virtually the whole area of south central Kassala Province has been cleared for agriculture (primarily mechanized).

3.0 Classification of the vegetation of the Sudan

The stratification based on the LANDSAT imagery denotes only density type classification without any clue to the vegetation classification type as shown in ecological classification. Therefore, a chapter on the ecological classification of the Sudan was deemed important to work out the total volume of the different strata and the allowable cut.

Sudan is a very large country with great variation in natural vegetation. The diversity and density of Sudan's vegetation ranges from the desert-type in the north to rain forests in the south. This variation is an outcome of ecological factors responsible for the formation and distribution of plant species. There is a broad correlation between the amount of rainfall and soil texture, and the height, diversity and thickness of the vegetation that they support. Man can also be considered as an important factor in determining the types of trees and grass that grow, because apart from the effects of cultivation, grass fires, which annually sweep across more than half the country, are almost invariably of human origin. These ecological factors can be summarized as follows:

3.1 Ecological factors

3.1.1 Soils

The following is a general classification of soil types which occur in the Sudan and which have a direct influence, together with rainfall, on the formation and

distribution of vegetation types.

3.1.2 Desert soils

These soils are found in the northern desert and semi-desert parts of the Sudan that receive less than 200mm mean annual rainfall. The soils are produced by the action of erosion. Nubian sandstone rocks are eroded by the action of heat and blown sand, and from skeletal soils underlying gravel and clay flats. The main characteristics of these soils are that they are unstable, loose and windblown. Under the influence of the prevailing norht-easterly winds, the loose sandy soil is blown in sheets moving towards the south forming what is known as "desert creep".

3.1.3. Stabilized sand dunes (qoz)

To the south of the desert and semi-desert belts, large areas of western and the northern parts of central Sudan are covered by stabilized sand dunes. They consist of large-grained red sand making about 40% of the soil composition, with PH values varying from 5 to 9, and with little water-holding capacity. Their content of mineral nutrients and organic matter is low, but they have a high water permeability. These sand dunes remain stable if left undisturbed, but the combined action of shifting cultivation, overgrazing and other human activities is changing the stability of the dunes and gradually reverting them to the unstable sands of the semi-desert.

3.1.4 Clay plains

These soils, often known as "badob" in Arabic, are dark, heavy alkaline, almost impermeable, soils. They cover large plains in eastern Sudan around the White Nile and Blue Nile. They have a clay content varying from 60% upwards and are alkaline (PH approximately 9.0). The lower horizons are hard concretions of gypsum and calcium carbonate. In the dry season this soil is characterized by shrinkage and the formation of deep cracks, which close up in the rainy season. Excess water is not absorbed and such action leads to flooding during the rains. Non-cracking clays occur in many small, scattered areas with a hard pan during the dry season and surface run-off during the rains.

3.1.5 Red-ironstone soils

These occur on undulating ground in southern Sudan, where the rainfall exceeds 800mm. They consist of red, heavy, sandy loam of various depths overlying hard layers of pea-iron nodules or harder ironstone rocks. The depth of the layer below the surface varies from a few centimeters to a meter or more. In places the upper layers have completely eroded to form a flat ironstone pavement. Generally, the soil is acidic and the PH value ranges between 5-7. Acidity increases with depth.

3.1.6 Silty soils

These are of alluvial origin, where small particles of silt are carried by annual and seasonal floods and deposited along banks of rivers and valleys and on flood plains. The important characteristic of this soil is that it is light and well-drained. It can carry a rich growth of annual and perennial vegetation and can form

dense forest (as one finds in the southern region).

3.1.7 Hill soils

These soils are variable in composition and texture according to the nature of the parent rocks. In elevated sandstone hills and igneous formations, rapid erosion continually forms alluvial deposits. The volcanic formation of Jebel Marra has produced a soil of volcanic tuff and ash. These hilly soils carry a remarkable variety of vegetation, depending on altitude and rainfall.

3.2.0 Climatic factors

3.2.1 Rainfall

Generally, rainfall plays a major role in the formation and support of vegetational growth in a country that can be described as generally arid or semi-arid.

In the Sudan rainfall increases gradually from north to south. At Wadi Halfa in the north the rainfall is 0.mm, increases steadily to 500-600mm in central Sudan and reaches its maximum of 1400mm at Yambio and Meridi. The area of Jebel Marra, Darfur, receives higher rainfall due to the effect of altitude. The Toposa area in s.e. Equatoria receives less rainfall than areas at the same altitude and latitude to the west.

In the central parts of the country rains usually fall in the summer for 4-5 months, lasting from May until October. In the southern region the rainfall can extend up to 10 months starting in March and continuing until November. The Red Sea hills and the coastal plains receive winter rains in December, January and February in addition to short summer showers.

The effect of rainfall on the vegetation type is obvious. The density and diversity of vegetation increases with the increase of rainfall. In the northern areas, we find desert and semi-desert types, and in the central areas, savannah types of vegetation, while in the southern Sudan we find some rain forests.

3.2.2 Temperature

The mean maximum and minimum temperatures in the country tend to decrease as one goes southwards. For example, at Abu Hamad (in the far north), the mean maximum temperature is 37°C and mean minimum is 21.4°C. At Meridi (in the south) the mean maximum is 18.1°C. Higher temperatures are generally associated with higher rates of evaporation increasing from the south to the north.

3.2.3. Topography

The Sudan is essentially a country of vast plains extending over the main central and eastern areas. The plains are mostly flat, interrupted by stabilized sand dunes and a few widely separated groups of hills and mountains. The country is divided from south to north by the Nile and its affluents.

Generally speaking, therefore, the effect of topography on vegetation is limited and only confined to:

(i) the mountain massifs on Jebel Marra (Darfur), and Imatong and Dongotona Mountains (Equatoria).
(ii) the smaller hills of the Nuba Mountains (Kordofan), Red Sea (eastern region), and Ingessana Hills (Blue Nile).
(iii) the upland country of Southern Sudan.
(iv) the Nile Valley and its tributaries.

3.3.0 Biotic factors

3.3.1 Man and his animals

The absence of land use planning together with a lack of application of essential principles of conservation has led in many parts of the country to severe land deterioration and vegetation loss. In the Sudan, traditional cultivation is practised in many parts of the country. This has led to land exhaustion and caused the removal of vegetation cover in areas around cultivated land. These harmful practices are more critical on marginal lands (low rainfall, high temperature, poor soil) which are threatened by soil erosion and desert creep. Moreover, the Acacia senegal belt and Acacia seyal clay belts are threatened by this unwise land use which has caused disappearance of the existing flora and their replacement with other species of less importance such as Acacia nubica.

The most destructive form of land use at present is mechanized farming. It is spreading over vast areas in the clay plains of central Sudan, especially in the Blue Nile, White Nile, Kassala and Southern Kordofan provinces. This practice is leading to harmful effects on the existing ecosystem as well as on the type of vegetation cover itself. The final result is that many native species have disappeared in areas under severe human and livestock pressure.

Animals contribute greatly in determining the nature and distribution of the vegetation cover in the Sudan. Grazing in central Sudan is directed in a northern movement during the rainy season and southern movement during the dry season. These movements from north to south and vice versa have created distinct vegetation belts, especially in central Sudan. Overgrazing under difficult conditions leads to the disappearance of plant cover, which in turn increases soil erosion and desertification. The Acacia senegal belt in Kordiofan and Darfur has suffered greatly in the past drought years, particularly during the 1970s. The harmful effects of overgrazing are presently more significant in north and central Sudan, and less severe in the south.

4.1.0 Classification of vegetation

The vegetation of the Sudan is usually divided into 7 principal vegetation regions. The classifications are broad; boundaries are diffused and sometimes impossible to draw. The borders of the fourteen (14) strata that have been drawn in the present series (see vegetation map and table) are based on available information compiled from more recent works on the vegetation of the Sudan. Traditionally, the Sudan has been divided into the following standard zones (which can be generalized to the fourteen strata defined above):

1) Desert
2) Semi-desert
3) Low rainfall woodland savannah
4) High rainfall woodland savannah
5) Rain forest
6) Flood region
7) Montane region

4.1.1 Desert

This region lies north of latitude 16°N and includes both the Nubian and Libyan desert. It excludes the whole of the Red Sea hills to a width of 100-150km from the sea.

The annual rainfall varies between 0-50mm and it is sporadic in both time and place. Away from the Nile, vegetation is extremely scanty and is generally found in depressions or along seasonal water courses ("khors"). In these water courses ephemeral herbs and grasses and acacia especially Acacia tortilis and Acacia ehrenbergiana may be found. The more common species are Aristida papposa, Panicum turgidum, Fagonia cretica, Indigofera sp., Aerva javanica, Cassia senna, Cleome chrysantha, Tribulus macropterus, Morettia philaena and Salsola bargosoma.

Moving toward the Nile the desert environment is modified to support some woody species like the palms Phoenix dactylifera, Hyphaene thebaica and some Acacias like Acacia tortilis, A. nilotica and A. albida associated with Capparis decidua, Ziziphus spinachristi, Tamarix aphylla, Balanites aegyptiaca and Calotropis procera.

4.1.2 Semi-desert

The area described as semi-desert lies between the desert and the "low rainfall woodland savannah". It includes the Butana plains, the Gash delta and the Red Sea coastal area (i.e. the area with annual rainfall between 50-300mm). Rainfall in this area is strictly confined to three months: June, July and August.

The natural vegetation in this region is thin and consists of seasonal herbs and grasses and deciduous, thorny scrub.

In the northern parts of this region hard soils alternate with sand dunes and rocky outcrops and receive low amounts of rainfall. This accounts for the sparsity of plant cover. Where water collects, Acacia tortilis, Capparis decidua, Cadaba sp. and Maerua may grow. The dry conditions of the north merge into a slightly modified environment. In this area limited cultivation is supported and grazing is practised, especially near villages. The natural vegetation consists of Acacia ehrenbergiana, A. nubica, besides ephemeral grasses such as Aristida, Schoenfelda gracilis, Cenchrus setigerus, Panicum turgidum, Combopogan proximus, Sporbolus humfus and Cenchrus biflorus which grow locally on loose sandy soils. The Nile banks carry Tamarix amphylla, Acacia nilotica and Ziziphus spinachristi. In the southern part of the region, local variations in soil types influence the vegetation. The sandy hills and plains in the west carry A. Senegal and Leptadenia pyrotechnica. Gravelly and rocky outcrops carry Commophora africana, Acacia mellifera, Boscia senegalensis, Acacia tortilis, and a sub-species of raddiana, while the ground flora consists of Aristida

glumosa, Blephares spp., Cymbopogan proximus, Tepharosa nubica, Indigofera spp., Cadaba glandulosa, and so on. In the eastern parts of the region, the soils range between light and heavy dark clays. The dominant species are Acacia nubica. The ground flora consists of Blepharis edulis, Ipomoea cordofana, Ocimum americana, Cymbopogan nervatus, Sehema ischaemaidis, Schoenfelda gracilis and Aristida sp.

4.1.3 Low rainfall woodland savannah

Here the rainfall ranges between 300-800mm. In this region trees are higher, from 3 to 5 meters in height, and grow so close together that their branches touch. However, they do not check the growth of grasses. This region lies in the central areas of Sudan, on clay to the east and on sand to the west. The former subdivision is dominated by Acacia mellifera in dense thickets which alternate with patches of short grasses. Other species include Boscia senegalensis, Cadaba glandulosa, Cadaba rotundifalia, Dichrostachys cinerea. A.Seyal and Balanites aegytiaca occur in water-receiving sites. The grass cover consists of Hyperrhenia sp., Cymbopogan nervatus, Sorghum purpureosericeum, Seteria verticillata and Cenchrus ciharis. Near the Gash river are large stands of Tamarix aphylla, Ziziphus spinachristi, Acacia nilotica and Cordia rothic. Along the Blue Nile and its tributaries in this area Acacia nilotica forests attain their best growth.

Moving westwards to Kordofan and Darfur, the Acacia senegal belt stands on the sandy "qozes" (stabilized dunes). Further south, it is found mixed with other species mainly Combretum cordofanum, Dalbergia melonoxyelon and Albizia amara. The patches of Acacia senegal usually follow shifting cultivation. On the higher rainfall area (above 600mm) vegetation tends to increase in density. Terminalia, Anogeissus and Prosopis savannah woodland are to be found. The dominant trees are Terminalia laxiflora, Sclera caryabirrea, Anogeissus leiocarpus and Prosopis african.

On rocky ground in this region Boswellis papyrifera grows in hills round Zalingi, Ingessana and Nuba Mountains, and Oxytenanthera abyssinica grows in the valley between hills. At the foot of the hills Sterculia setigera and Anogeissus leiocarpus grow. Grasses include Chloris pilosa, Hyperrhenia confinis, Brachiaria lata, Sporobolus marginatus, Eragrostis sp. and Andropogan gayanus. In the south-east corner of the Sudan, short grass vegetation grows similar to that found in the Acacia mellifera zone.

It is very important to point out that this region, the "low rainfall savannah", is subject to extensive cultivation (either mechanized or shifting) as well as extensive charcoal production.

The present rate at which the natural vegetation is cleared for cultivation and charcoal supply is very rapid. The largest mechanized agricultural schemes in the country lie within this region (such as El Dali, El Mazmum, Kumfur, Agadi, El Grabein, El Migeinis and the agricultural schemes in Gedaref area). Due to this heavy cultivation only relics of the original forest remain in these areas.

4.1.4 High rainfall woodland savannah

This region is particularly characterized by ironstone and occupies most of the southern provinces of Bahr El Ghazal and Equatoria. The red ironstone soil supports

rich, diverse types of vegetation, mostly broad leafed trees with a few thorny species. Coarse, tall, perennial grasses predominate, thus making fires generally more fierce than in other regions. Khaya senegalensis, Isoberlinia doka and Anogeissus leiocarpus occur in pure stands under rainfall between 900 and 1300mm. Butyrospernum niloticum becomes dominant after clearance of other species in the process of shifting cultivation.

The grass cover contains tall grasses like Andropogon gayanus together with Hyperrhenia species. Other grasses include Ctensum elegan, Loudetia simplex and Sporbolus festivus.

4.1.5 Tropical rain forests (More than 1300mm of rainfall per annum)

Within the woodlands, there are very few small patches of rain forests at Lotti, Laboni and Talanga, east of the Nile, and at Azza and on the Aloma plateau to the west. Celts zenkeri and Chrysophyllum albidum appear to represent the climax vegetation. In the gallery forest Khaya grandifoliola, Syzygium owaniensis, Diospyros mespiliformis, Cola condifolia, Mitrogynia stipulosa, and Chlorophora excelsa are found. Other rain forest occur at higher altitudes in the Imatong mountains, which contain rich flora.

4.1.6. Flood region

The flood region occupies an area of 95,000 sq. miles of the Sudan. It consists of the various rivers with their banks of floating vegetation and areas where drainage is poor and water stands for varying periods of the year, either from rainfall or from overflowing by the Nile. The area is divided into highlands, intermediate lands and swamps. The first region is rarely flooded and its soil is composed of sand and sandy loam. It is dominated by the palm type, broad-leaved types and mixed Acacias. The intermediate land is inundated during the rainy season and is the largest constituent of the region. It is mostly grassland with some areas of Acacia seyal and Balanites savannah. The last division is dominated by Cyprus papyrus, Echinochloa stagnina and E.pyramidalis.

4.1.7 Montane vegetation

Montane vegetation can be divided into four main mountain areas in the Sudan; Imatong and Dongotona Mountains, Didinga Mountains, the Red Sea hills and Jebel Marra.

4.1.8 The Imatong and Dongotona Mountains

These mountains are in Equatoria Province. Below 1500 meters and in wetter areas vegetation such as Boswellia papyrifera and Terminalia brownii are found. Above 1500 meters the vegetation may be divided into three zones:

a) Lower montane forest 1500-2600 meters where Syzygium sp., Olea hochstetteri and podocarpus provide the climax vegetation.

b) Upper montane vegetation 2600-3000 meters where Podocarpus and some Olea sp. constitute the climax except in certain areas.

c) Above 3000 meters the Ericaceous zone where Erica arborea and Myrica salicidelia are dominant.

4.1.9 The Didinga Mountains

These are also in Equatoria. The highest point is Mount Lotuka. The summit is similar to the "lower montane forest" but elsewhere fires have reduced vegetation to grassland with a few relic trees of Juniperus procera and Olea chrysophylla.

4.2.0 The Red Sea hills

These are on the north-eastern part of the Sudan. Pure forests of Juniperus procera with Olea chrysophylla and other species are found around the edges. Further north only Olea chrysophylla remains mixed with trees less markedly montane in character. In the drier areas Euphorbia abyssinica and Dracaina ombet are common.

4.2.1 Jebel Marra

Up to 2000 meters the area is largely cultivated along the fields. Cordia africana, Thespesia garkeana and various Ficus spp. appear. The dominant grasses are Cymbopogan and Hyparrhenia spp. Between 2000 meters and 2500 meters Olea laperrini and Acacia albida are found with Ficus sp. and Salix safsaf near streams. Most of the zone above 2500 meters is covered with dwarf grasses of Hyparrhenia multiplex with scattered Olea trees.

These zones correspond roughly with the fourteen (14) strata set out earlier with less specificality (e.g. delineation of cultivated areas, swamplands, and so on).

TABLE 2: FORESTRY RESOURCES IN SUDAN BY PROVINCE AND REGION

REGION AND PROVINCE	TOTAL AREA (HECTARES)	AVERAGE VOLUME (m^3/HECTARE)	TOTAL VOLUME (m^3)	ANNUAL ALLOWABLE CUT (m^3)
EASTERN[1]	2,748,065	2.55	7,007,855	234,602
Red Sea	-	-	-	-
Kassala	2,748,065	2.55	7,007,855	234,602
CENTRAL	5,123,790	4.98	25,532,325	886,256
Blue Nile	4,957,440	4.90	24,313,794	831,198
White Nile	157,450	3.93	618,051	21,602
Gezira	8,900	67.47	600,480	33,456
KHARTOUM[1]	5,000	60.00	300,000	30,000
KORDOFAN[1]	11,628,000	10.56	122,827,800	2,985,994
South Kordofan	11,628,000	10.56	122,827,800	2,985,994
North Kordofan	-	-	-	-
DARFUR[1]	17,693,300	26.97	477,199.800	9,587,083
South Darfur	17,693,300	26.97	477,199,800	9,587,083
North Darfur	-	-	-	-
NORTHERN[1]	-	-	-	-
Northern	-	-	-	-
Nile	-	-	-	-
Total Northern Region, scrub and semi-desert[1]	4,200,000	4.76	19,992,000	1,332,800
NORTHERN SUDAN SUB-TOTAL[1]	41,398,155	15.77	652,859,780	15,056,735
SOUTHERN	71,095,683	18.75	1,332,953,362	29,300,346
Buhayrat	6,525,400	15.03	98,069,800	2,911,378
Jonglei	11,863,900	3.76	44,643,700	2,097,915
Bahr El Ghazal	11,733,900	34.94	410,037,200	8,336,555
E. Equatoria	10,818,150	17.39	188,084,896	4,328,640
W. Equatoria	6,982,733	61.76	431,275,066	6,952,831
Upper Nile	23,171,600	6.94	160,842,700	4,673,027
TOTAL SUDAN	112,493,838	17.65	1,985,813,142	44,357,081

[1] Forestry Administration sources and Moh. El-Amin Mukhtar estimate the total area of desert and semi-desert scrub and brush wooded area at approximately 4,200,000 hectares, with a total growing stock of 19,992,000m^3, an average growing stock volume per hectare of 4.76m^3, and an annual allowable cut of approximately 1,332,800m^3. These resources are scattered and are found primarily in Nothern Kordofan and Darfur, Northern Nile, Khartoum and Red Sea Provinces. Because of the inability to assign these resources to particular provinces, all estimates are included in both Northern Sudan sub-totals and in the estimate of Sudan's total forestry resources.

SOURCE: NEA and Forestry Administration.

TABLE III: AREAS OF FORESTS AND VOLUME OF WOOD PRODUCED

PROVINCE	AREA IN HECTARES			VOLUME IN (000)m^3			ALLOWABLE CUT TOTAL		
	PL	N(000)	Total(000)	Planta-tion	Natural	TOTAL	PL(m^3)	N(000)m^3	Allow-able cut (000)m^3
E. Equatoria	9525	10565	10575	1566	205422	206988	29994	4511	4541
W. Equatoria	3350	6983	6986	268	431276	431544	4467	6951	6956
Bahr el Ghazal	4600	11430	11434	690	410587	411277	9857	8348	8358
Buhayrat	-	6525	6525	-	199676	199676	-	4605	4605
Jonglei	-	11926	11926	-	56828	56828	-	1592	1592
Upper Nile	393	11701	11702	4	73512	73512	197	2282	2282
S. Kordofan	3383	11628	11631	39	122828	122867	1942	2986	1988
S. Darfur	4316	17693	17697	118	477199	477317	8680	9587	9596
White Nile	6622	155	162	189	463	652	7853	15	23
Blue Nile	27493	4944	4971	1398	10999	22397	52975	707	760
Kassala	36840	2746	2783	469	6384	6853	22482	212	234
Gezira	8900	-	9	600	-	600	40104	-	40
D. Darfur	5127	-	5	126	-	126	3314	-	3
N. Kordofan	9501	-	9	95	-	95	4715	-	5
N. Region	1000	-	1	120	-	120	8000	-	8
Khartoum	1870	-	2	72	-	72	7013	-	7
TOTAL	122920	96296	96419	5754	2005174	2010928	201629	41796	41998
S. Region	17868	5913	59148	2528	1377301	1379829	44515	18189	28333
N. Region	105052	37166	37271	3226	627873	631099	157114	13507	13664

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