PN-AAT-272

41119

PREASSESSMENT OF NATURAL RESOURCE ISSUES IN SUDAN

Institute of Environmental Studies
University of Khartoum
P. O. Box 321
Khartoum, Sudan

Supported by a grant from Man and the Biosphere Program (MAB) with assistance from US-AID's East African Regional Economic Development Service Office (REDSO) and from the Program for International Development, Clark University, USA.

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Jointly published by:

The Institute of Environmental Studies
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and

The Program for International Development
Clark University
Worcester, Massachusetts 01610
USA

Supported by a grant from Man and the Biosphere Program (MAB) with assistance from USAID's East Africa Regional Economic Development Service Office (REDSO).

1983

TABLE OF CONTENTS

		Page
Chapter One	Desertification with Special Emphasis on Carrying Capacity and Pastoral Resources Dr. Mustafa H. Suliman Mr. Ali Darag Ali	1
Chapter Two	Decreasing Energy Availability in Sudan with Particular Consideration on Rural Energy Supply Mohammed El Amin Mukhtar	28
Chapter Three	Pressure on Water Resources in Rural Areas Dr. M. O. El Sammani	47
Chapter Four	Deforestation Resulting from Clearing Land for Agriculture, Grazing Pastures, and Charcoal Production Professor Hassan A. Musnad	81
Chapter Five	Reduced Agricultural Productivity in Irrigated Areas with Particular Reference to Silting in Reservoirs, Rivers, and Lakes Omer El Badri Ali	101
Chapter Six	Soil Degradation Resulting from Mechanized Agriculture in Rainfed Areas Dr. Amna Basher Homoudi	115
Chapter Seven	Health Problems Arising in Irrigated Agricultural Areas Dr. Kaidar Abu Ahmed	138
Appendix	The Environmental Context of Development in Sudan	151
	Map (Follows page 158)	
Literature Cited		159

LIST OF FIGURES

Figure		Page
1.1	Arid Climates in the Sudan	4
1.2	Political Regions	5
1.3	Seasonal Movements of Nomads in Kordofan	15
1.4	Misuses of Rangelands as Related to Desertification in the Sudan	19
3.1	Population Distribution	49
3.2	Northern Region: Drinking Water Envelope	51
3.3	Eastern Region: Drinking Water Envelope	53
3.4	Khartoum Province: Drinking Water Envelope	55
3.5	Central Region: Drinking Water Envelope	56
3.6	Kordofan Region Drinking Water Envelope	58
3.7	Darfur Region: Drinking Water Envelope	62
4.1	Principal Geological Formation Tree Vegetation	83
4.2	Important Grass Cover Types and Desertification Classes Based on Range Condition Classification	84
4.3	Distribution of Population	85
4.4	Principal Soil Types and Their Approximate Distribution	85
4.5	Principal Boundaries of Sands/Clays and Red Ironstone Soils	86
5.1	Major Irrigated Schemes	103
5.2	Mean Current Velocity and Concentration of Suspended Matter in the Blue Nile at Khartoum: Flood Season, 1967	107
5.3	Mean Current Velocity and Concentration of Suspended Matter in the Blue Nile at Khartoum: Flood Season, 1968	108
5.4	Mean Current Velocity and Concentration of Suspended Matter in the Blue Nile at Khartoum: Flood Season, 1969	109
6.1	Sudan Rainfed Mechanized Agricutural Areas	118
6.2	Sudan Mechanized Farming Corporation Organization 1982	132
7.1	The Blue Nile Health Project	145

LIST OF TABLES

Table		Page
1.1	Ecological Zones and Area Affected by Desertification	6
1.2	Vegetation Zones of the Sudan and Estimated Carrying Capacities	9
1.3	Proposed Expansion of Rainfed Mechanized Farming	13
1.4	Amount of Forage Removed by Seasonal Fire	14
1.5	Livestock Population in the Sudan (1966)	16
1.6	Animal Populations in the Sudan and the Percentage of Natural Herds in Kordofan and Darfur	17
1.7	Estimated Total Forage Production	18
1.8	Range and Pasture Administration HQ/Structure	26
1.9	Working Staff in Natural Resources Conservation	27
2.1	Energy Consumption by Sector	31
2.2	Breakdown of Total Energy Consumption by Source	32
2.3	Dependence of the Economic Sectors on Energy Sources Expressed as a Percentage of the Total Energy Requirement, as in the year 1980	34
2.4	Southern Region Energy Consumption by Economic Sectors - 1980	35
2.5	Central Region Energy Consumption by Economic Sectors - 1980	37
2.6	Darfur Region Energy Consumption by Economic Sectors - 1980	38
2.7	Kordofan Region Energy Consumption by Economic Sectors - 1980	39
2.8	Eastern Region Energy Consumption by Economic Sectors - 1980	40
2.9	Khartoum Province Energy Consumption by Economic Sectors - 1980	41
2.10	Northern Region Energy Consumption by Economic Sectors - 1980	42
2.11	Energy Requirements 1980, 1985, 1990	43
2.12	Energy Consumption by Regions - 1980	44
3.1	Annual Water Requirements by User Category	64
3.2	Sites, Studies for 1969/70 Programme	69-71
5.1	Nile Waters Silt Load During Flood Period	105
6.1	Deserted Farms in Simsim Project	117
6.2	Areas of Mechanized Farming in Million Feddans	117
6.3	Distribution of Areas of State Farms	120
6.4	Crops and Areas Cultivated in the State Farms in 1981/82	121
6.5	Areas, Production and Average Yield of Main Crops under Rain-fed Mechanized Farming, 1969-1972/73	124
6.6	Areas, Production and Average Yield of Main Crops under Rain-fed Mechanized Farming, 1973/74-1976/77	125
6.7	Areas, Production and Average Yield of Main Crops under Rain-fed Mechanized Farming, 1977/78-1981/21	126

Table		Page
6.8	Average Yield of Sorghum in Kilograms/Feddan and Rainfall	127
6.9	Average Yield of Sesame in Kilograms/Feddan and Rainfall	128
6.10	Average Yield of Cotton in Kilograms/Feddan and Rainfall	129
6.11	Yield/Feddan for MF in Sudan and in Australia	130
6.12	MFC Manning Situation	133
6.13	Machinery, Cars and Equipment by MFC at Different Stations	135
7.1	Cases of Malaria and Bilharzia, 1973-1981	140
7.2	Distribution of Malaria and Bilharzia by Provinces in 1981	141
7.3	Benefits/Costs	144
7.4	Annual Slide Positivity Rate of Malaria in Halfa Resettlement Area and Riverian Area	147

FOREWORD

The seven papers and maps presented in this assessment represent a unique approach to resource management needs in developing countries. First they provide a multi institutional approach. US-AID's regional office in Nairobi, the Regional Economic Development Service Office (REDSO), provided the methodological impetus; Sudan's Institute for Environmental Studies, University of Khartoum contributed the field work, substantive analysis, and actual written papers; the MAB Program (Man and the Biosphere) provided financial backing; East Africa's Regional Facility for Remote Sensing supplied most of the black and white maps; Clark University's International Development Program followed with assistance to produce the color map and publish the report. Although many individuals cooperated to complete the project, two deserve special mention. Dr. Gelal El Din El Tayeb, then Chairman of the Georgraphy Department, University of Khartoum organized the papers including identifying authors and following up on field work and writing. Brandon Robinson, Head of REDSO East Africa's Analysis Division, initiated the concept and provided the overall orientation for the work.

Second, the methodology is innovative. It assumes that a series of single sector approaches to resource problems are inadequate. Given that resource issues in Sudan incorporate several basic sectors including water, agriculture, forestry, livestock, health, and irrigation, the papers set out to analyze data in each area as they relate to all of the others. The methodology not only relies on the problem orientation but also assumes that resource problems require theoretical as well as practical reviews. For that reason, issues such as desertification, mechanical farming, or water policy are examined in general terms but also within the context of specific interventions that can ameliorate resource pressures. Finally, the methodology assumes that the best procedure to assess resource degradation is one which allows host- country experts and institutions to take the leading or dominant role in the analysis. National institutions have good access to local and national data, they have good understandings of national priorities, and they are in ideal positions to play a role in the continuous monitoring of resource trends and ways in which specific interventions might be managed.

As a third unique feature, these papers are part of a larger process related to resolving resource pressures in Africa. As a first step, an Environmental Profile of Sudan was prepared, with support from the MAB program. The profile identified the data base and information sources for Sudan as well as noted critical development issues. Stage two is the Energy/Natural Resource Assessment, as presented here. Its purpose is to review the nation's major development issues related to resource pressures and to place them in the context of a multi-sectoral setting. Stage three is one of synthesis which integrates studies such as the ones included in this assessment. Stage four, should it be deemed appropriate, is a larger data collection and analysis effort, sometimes called a multi-sector analysis, which reviews in detail the resource information base, the national institutional capabilities to manage resource problems, and the economic and environmental viability of particular interventions which the assessment has identified. The goal of the entire process is to build resource management needs and considerations into development planning and actions at every level of the process. The papers provide several important findings.

... food productivity in Sudan is declining at alarming rates;

... ninety-eight percent of household energy is derived from biomass, an

energy source which is rapidly disappearing in the northern half of the country;

... rates of tree cutting for fuelwood and charcoal are already exceeding legal limits and are accelerating;

... ill-advised sites for water points in semi-arid areas have been one of the greatest factors contributing to desertification;

... unregulated mechanized farming, especially in the central portions of the country, is depleting soil fertility, contributing to wind and wash erosion of the soil, and depriving nomadic communities access to their traditional grazing rotation cycles;

... siltation of rivers and reservoirs is seriously undermining the nation's ability to provide reliable flows of irrigation water and sustained generation of electricity;

... poorly supervised irrigation systems have led to rapid increase in the incidence of two serious water-borne diseases: malaria and schitosomiasis;

... livestock numbers relative to the grazing lands now available to them are over capacity, even for normal rainfall years. The advent of drought presses the resource base beyond its ability to produce and may be creating irreversible damage to the nation's long range agricultural and pastoral productivity.

All of these problems are lumped under the general heading of desertification -- the decline in productivity of the nation's soil and water.

Yet the authors do not despair. Two levels of recommendations emerge from the papers. One calls for interventions and action programs that could be implemented rather quickly. Among these immediate steps are:

... aggressive tree planting, in part as shelter belts to cut down on wind erosion and in part as sources of fuelwood and charcoal. A model of local participation, as developed by the Sudanese Council of Churches, is proposed as an examplar to be considered for expansion;

... locating water points where better regulation of use can be maintained. In particular, grazing areas adjacent to water points must be managed by local committees who have authority to limit numbers and use.

... improved control of soil and run-off into rivers and reservoirs. This is especially true of the larger irrigation schemes and reservoirs such as Roseires, Rahad, Gezira, New Halfa, etc;

... improved systems for transporting animals. Better transportation will increase incentives and make easier and cheaper the pastoralists' task of taking stock to market, thereby reducing livestock pressures;

... closer regulation of land use under mechanized agriculture. Enforcement of fallow cycles and crop rotation is high priority. Incentives to use fertilizer and soil rehabilitation techniques is also encouraged;

... improved incentives to clean irrigation canals to reduce breeding sites for malaria and schisto carriers and improve the efficiency of water delivery to farmers;

... sand dune fixation, small water catchment schemes, long term rewards for forestry protection, and improved efficiency in energy consumption.

These short term steps are drawn from known experiences and, in varying degrees, have worked successfully either in Sudan or in similar climatic and cultural settings.

The second level of recommendation relates to longer range planning. Virtually all authors agree that Sudan's greatest deterrent to combating desertification is lack of an integrated land use policy. All note that there is high priority to develop guidelines for land use that are compatible with sustaining power of the resource base. To construct such a policy requires a number of considerations including:

... problems involve several ministries - recognition that resource problems are closely interrelated, involving several sectors and several disciplines. Creation of an integrated land use policy will require close cooperation among a number of ministries and agencies;

... resource data - land policy requires carefully considered land uses, based on sound assessments of the resource base. In that resource data are uneven and frequently unavailable, a major effort is needed to upgrade the present natural resource information systems;

... regulation - land use policies have no purpose in the absence of a means to enforce them. Ministries need authority to regulate land users to assure that policies are carried out;

... monitoring - resource information is not a static data base. Means are required to monitor and update the information, both as a means to assure that policies are being carried out as well as to make adjustments as policies and technologies for land use practices change.

... land classification systems - decisions need to be made concerning the type of land use classifications that are required. One approach is to use agro-ecological zones, as developed by several ministries in Kenya. Another approach is the Land Systems and Crop Suitability approach prepared for Rukwa Region in Tanzania. Other options include soil analyses such as FAO has carried out in Kordofan or tree species potentials as underway in a number of countries. Whatever the land classification system, it is important that it:

a. incorporate both physical and socioeconomic data;

b. be compatible with priorities and capabilities of local institutions;

c. be limited in the amount of data collected and monitored.

... participation - land use policies must be constructed in full cooperation with local farmers and pastoralists who are themselves the principal users of the land.

If these papers stimulate action for new development and resource management interventions and carry forward the discussions among donors and the Sudan government to develop a resource assessment and land use policy, they shall have served their purpose.

We wish to thank Arnold Gray for assistance in editing.

Richard Ford
Clark University

CHAPTER ONE

Chapter one addresses the problem of anthropogenic desertification--the desiccation of an ecological region as a result of human activity. Three levels of desertification are identified ranging from light to moderate to severe. The three levels can be distinguished by the grass species that predominate in the region. Aristide is dominant in the severely desertified regions which include Northern Province, North Kordofan and North Darfur. Censhrus and Andropogen dominate the moderate regions which include the low rainfall woodland savannah. Sorghum dominates the eastern lightly desertified zone with Andropogen and Hyparrhenia in the central and western high rainfall savannah. The levels are related to manifestations of desertification which include shortages of fuelwood, deterioration of rangelands, socioeconomic impacts and others. Suliman and Ali Darag cite four major causes for desertification:

1. Conversion of rangelands into cereals cultivation;
2. Destruction of pastoral resources through fire;
3. Nomadic use and lack of grazing management;
4. Overgrazing.

The chapter then proceeds to describe the major problems and causes of desertification. The authors discuss interventions which have been attempted to counter the desertification problem and point out how unexpected impacts have sometimes aggravated rather than alleviated desertification. For example, pastoralists are often the victims of their own success. Finally, the chapter outlines the institutional structure that currently enables the Sudanese government to manage anti-desertification activities.

Desertification with Special Emphasis on Carrying Capacity and Pastoral Resources

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INTRODUCTION

Desertification, as defined by the UN Conference on Desertification held in Nairobi in 1977, is the diminution or destruction of the biological potential of the land which can lead ultimately to desert-like conditions. Apparently one might think of the problem of desertification as something new to mankind. According to the definition, however, the phenomenon probably started when man shifted from subsistence to commercial utilization of land and natural resources, especially in arid and semi-arid regions where the ecological balance is naturally fragile.

Creation of desert-like conditions is either a natural process or induced by man's use of the land. The former is termed climatic desertification and is the mere product of aridization of deserts and semi-deserts that took place as early as the Pleistocene (Dov Nir, 1974). The later is termed anthropogenic desertification and is brought about by man's cultural and economic activity.

In the Sahel region in general and in the Sudan in particular the phenomenon of desertification is largely anthropogenic. Misuse of renewable natural resources such as overstocking of rangelands, overcutting of woody plant

species, cultivation of marginal lands with cereal crops, and frequent man-made outbreaks of savannah fires are among the main causes of desertification. The impact of this misuse is further accentuated by the frequent occurrence of drought and rainfall variability.

During the prolonged Sahelian drought of 1968-1973, the problem of desertification in the Sahel region proliferated into a devastating and catastrophic phenomenon. The havoc took many human lives, left hundreds of thousands of people without shelter, and swept away as many as half the region's livestock population.

The goal of this paper is to survey the problem of desertification in Sudan, focusing on overstocking of rangelands and mismanagement of pastoral resources as a major cause of anthropogenic desertification. Other related causes will be addressed whenever possible. Corrective measures with regard to sound range management and improved techniques will be discussed in depth.

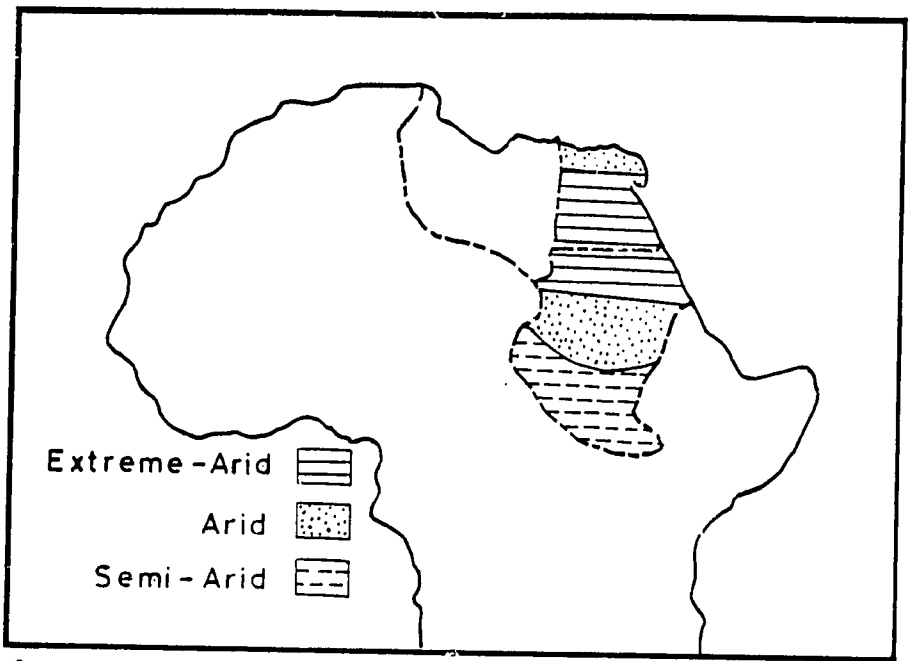
CLIMATIC DESERTIFICATION

The first climatological problem analyzed by UNSECO's arid-zone project was the definition of arid lands and their distribution over the Earth (Walton 1969). The major difficulty in arriving at an agreed definition of a desert and its subdivision is that so many factors are involved, including rainfall, temperature, insolation, evaporation, relative humidity, vegetation and soil composition. Thornthwaite (1948) used an index based upon the relation between precipitation, potential evapotranspiration, and soil storage. Koppen (1931) determined the borderline of aridity as a certain ratio of temperatures to precipitation, while Meigs (1953) divided arid zones according to the amount of rainfall, seasonality of rainfall and temperatures.

Whatever definitions one adopts, almost the entire territory of the Sudan is included within the boundaries of aridity (Figure 1.1). From the standpoint of climatic changes, there is no reason or conclusive evidence to suggest that the macroclimate of the region has undergone any significant changes since the Pleistocene (Soil Conservation Committee, '1944') and (DECARP, 1976). However, the majority of authors who have studied the role of climatic factors in desertification (e.g., Dov Nir, 1974 and Ibrahim, 1982) have stressed the fact that areas prone to desertification are naturally characterized not only by meagerness of rainfall but also by irregularity, uncertainty and wide variability in amount, time, and distribution of precipitation. Further, annual rainfall patterns are characterized by high frequency of drought occurrence.

During the last 75 years, several droughts occurred in the Sahel. Reported catastrophic droughts came in 1914-1919, 1939-1943 and the so-called 'great' drought of 1968-1973. The adverse effects of drought on vegetation cannot always be reversed in succeeding years of favorable rainfall.

ARID CLIMATES IN THE SUDAN



Source: McGinnies et.at 1968

Figure 1.1

ANTHROPOGENIC DESERTIFICATION

Desertification induced by man's mismanagement in arid and semi-arid regions is more serious than climatic desertification. It is primarily degradation and retrogression in the biological ability of the land to produce under unbalanced utilization. The danger of anthropogenic desertification stems from the dynamism of human population in these fragile ecosystems and the subsequent increase in land utilization to meet the growing demand for food, fuel, and fiber.

UNEP (1981) estimates the land lost to anthropogenic desertification to be 9.1 million square kilometers. This area potentially could support approximately 400 million people or 12.8 percent of world population. The annual rate of land lost to desertification is estimated at 50,000 square kilometers (UNEP, 1981). This rate is expected to rise as pressures on the land increase due to growing human population growth and lack of alternatives to traditional livelihood systems.

MAGNITUDE AND EFFECTS OF DESERTIFICATION IN THE SUDAN

Magnitude of the Problem

Excluding the proper deserts of the Sudan (The Libyan Desert and the Nubian Desert), the areas affected by desertification in the Sudan can be categorized into three classes:

- severely desertified areas;
- moderately desertified areas;
- lightly desertified areas.

The severely desertified areas have been estimated as 650,000 square kilometers (DECARP, 1976). This area includes most parts of Northern Province, Northern Kordofan, and Northern Darfur (Figure 1.2). Moderately desertified areas are essentially those classified as low rainfall savannah on both clay and sandy soils. Most parts of high rainfall savannah and montane vegetation can be considered as lightly desertified areas.

POLITICAL REGIONS

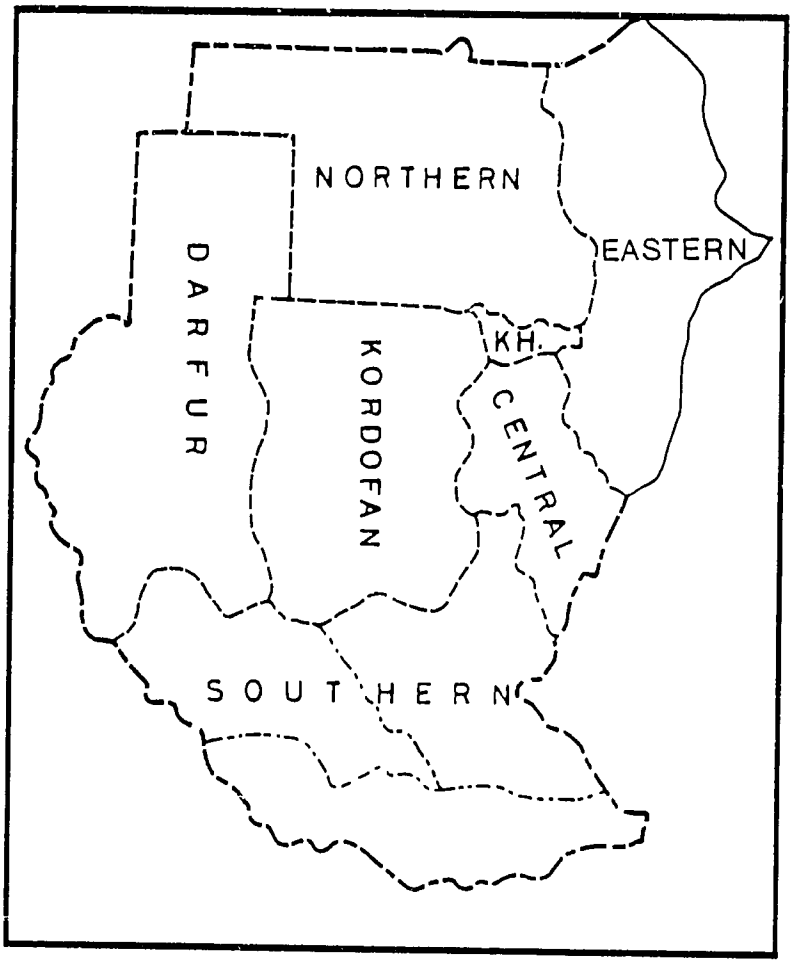


Figure 1.2

Although there is no precise quantification of the magnitude of the problem in Sudan, one can reasonably estimate the total area affected by all classes of desertification at approximately 1,528,000 square kilometers which constitutes more than 60 percent of the country (Table 1.1). When this area is added to the climatic desert which is 725,000 square kilometers, the total area of the desert and desertified regions will be approximately 2,253,000 square kilometers which is almost 90 percent of the total area of the Sudan.

TABLE 1.1

ECOLOGICAL ZONES AND AREAS AFFECTED BY DESERTIFICATION

		Rainfall (mm)	Total* Area sq. kms	Percent to total	Desertification classes**
I.	Desert	0-75	725,000	29	-
II.	Semi-desert	75-300	492,000	19.6	Severe (1)
III.	Low Rainfall Savannah	300-800	689,000	27.5	Moderate (2)
IV.	High Rainfall Savannah	800-1300	347,000	13.8	Light (3)
V.	Flood Region	800-1000	246,000	9.8	-
VI.	Montane Vegetation	Varies	6,000	0.3	-
	TOTAL		2,505,000	100.0	

* According to Harrison & Jackson - vegetation classification (1958).
** Field obser. and author's professional estimation based on range condition classification.

(1) 76 - 100% deterioration.
(2) 51 - 75% deterioration.
(3) 26 - 50% deterioration.

In 1975, Sudan's National Council for Research and the UN (UNESCO, UNEP) surveyed and mapped the areas affected by anthropogenic desertification north of latitude 12 where annual precipitation is between 100-400 mm. This area is essentially the semi-desert and part of the Low Rainfall Savannah zone. Lamprey (1975) found that the desert had advanced southward on an average of 90 to 100 km. during the period from 1958 to 1975. According to the rough method used, the rate of severe desertification in this particular zone is 5 to 6 km. per year. Although there is no quantitative projection for the extent of desertification in the future, one might conservatively say that even the rate of 5 to 6 km. per year is an underestimate. Should all factors and parameters associated with the process of desertification remain as they are, then the rate of desertification will probably continue on the order of 5 to 6 km. per year.

Effects of Desertification

Sudan's Desert Encroachment Control and Rehabilitation Program (DECARP) has worked out the effects of desertification on various aspects of Sudanese life. DECARP's work was published in 1976 and is considered to be the eminent source of information on desertification in the Sudan. The manifestations of desertification as surveyed by DECARP (1976) in the Sudan and later documented by UN Conference on Desertification in 1977 are: declining land productivity and food production, shifting sand dunes, shortage of fuelwood, deteriorating environmental quality, deterioration of range lands and pastoral resources, and the associated adverse socioeconomic effects.

Dwindling land productivity and food production have been documented by DECARP (1976). During the period from 1961-1973 production of major crops declined sharply due to the effects of increasing desertification. For example, in Kordofan Province the land area needed to produce the same amount of peanuts in 1973 was almost five times that required in 1961. For the same period, the decrease in sesame and sorghum production was approximately 20:1 and 8:1 respectively. Ibrahim (1978a) reported that the decline in millet production was almost 50 percent during the period 1960-1975 for the whole country.

Shifting sand dunes have also increased as a result of desertification. In Northern Kordofan and Northern Darfur Provinces, sand is continuously heaping over the formerly productive sandy and clay soils. The entire strip of the river Nile is subject to serious dune encroachment, particularly in the area between Delgo and Karima. As a result, thousands of fertile and highly productive acres have been lost to shifting sand dunes in Northern Province.

Shifting sand dunes have also endangered permanent water supplies as in Elodaya in Kordofan Province. In this particular town sand dunes have affected every aspect of life, especially burying agricultural land and filling hand dug wells.

Obtaining wood for fuel is becoming a serious problem in both villages and city centers. DECARP (1976) reported that wood for fuel and charcoal was once collected within 5-10 km. of Khartoum. Today it is transported 100 km. or more to the city.

Deteriorating environmental quality is exemplified by increased intensity and frequency of dust storms in various parts of the Sudan. It has been reported that the amount of airborne soil particles increased tremendously during the period following the great drought of the Sahel in 1968-1973 (UNEP, 1977). Concerning adverse socioeconomic effects of desertification, quoting DECARP (1976, 91-92):

> Migrations in search of water, land and forage have led to miserable living conditions and at time's confrontation, bloodshed and loss of human life.

Rangelands and Grazing Resources

Rangelands and natural grazing resources constitute approximately 60 percent of the total area of the country. This vast area is characterized by variations both in physical and biological features. Apart from a few areas recently covered by detailed resource inventories (Hunting Technical Services, 1962/1975), the only genuine work on the vegetation and the grazing resources of the country is that of Harrison and Jackson (1958). Their work is considered by most authorities as the most complete work pertaining to the grazing resources of the country. However, the method employed was approximate and needs to be revised. According to Harrison and Jackson, the country's vegetation can be classified into six ecological zones (Table 1.2).

Within the major ecological zones of the country there are several grass cover types which represent the major pastoral resources for both domestic and wild animals. From the standpoint of range management, important grass cover types include the following:

1. Aristida Types (AR)

Aristida occurs in the eastern part of the Libyan desert where vegetation is virtually absent except along intermittent courses or occurs as ephemerals that grow after rare showers and complete their life span within a few weeks.

Dominant grass species are:

- Aristida pungens
- Aristida plumosa
- Panicum turgidum (in wadis) tuman.

Within this type, a rather pecular area of 'Gizzu' occurs. Gizzu is an association or a group of species, probably having similar growth conditions and requirements. It makes its appearance if rain has fallen with the onset of intensely cold nights. In the order of their importance, Gizzu plants are:

- Indigofera bracteolate
- Neurada procumbens (Main provider of moisture for animals)
- Indigofera arenaria
- Aristida papposa
- Fagonia cretica

In the eastern part of this grass cover type, cenchrus setigerus becomes abundant on some sandy soils. Schima sp. occurs on drier and clay soils of this region, while Cymbopogon proximus does well on overgrazed areas.

2. Andropogan Types (AN)

Andropogan is a difficult type to characterize because of its association with hill areas and outcrops of basement complex rock with catena development of variable soils. In the order of their abundance, grass species are:

TABLE 1.2

VEGETATION ZONES OF THE SUDAN AND ESTIMATED CARRYING CAPACITY

Vegetation Zone	Area in sq. kms.	Range of Rainfall (mm.)	Carrying capacity (animal units/sq. mile)
Desert	725,000	0-75	Only about 20% of the area can be used for grazing. Carrying capacity 10.
Semi-desert	492,000	75-300	The used grasses are about 60% and average carrying capacity is 25.
Low Rainfall Savannah	689,000	300-800	Carrying capacity increases toward the South until we reach 45.
High Rainfall Savannah	347,000	800-1500	Carrying capacity between 60-75.
Flood Region	246,000	800-1500	Carrying capacity 65.
Montane vegetation	6,000		Carrying capacity is according to rainfall and distribution of water e.g. Jebel Mara 80 but in Red Sea Hills it is 10.

SOURCE: Harrison & Jackson, Vegetation Classification of the Sudan (1958).

NOTE: Data on carrying capacity in 1958, though slightly overestimated, can be used as a criterion to quantify desertification effects if compared with current carrying capacity.

- Andropogon gayanus
- Schoenefeldia gracilis
- Elyonuru royleanus
- Aristida sp
- Hyparrhenia confinis
- Setaria pallida
- Pennisetum sp
- Ctenium elegans

Most of these species occur on the baggara wet season grazing domain.

3. Cenchrus Types (CE)

Cenchrus dominate in the stable sandy 'Quze' of Kordofan Province. Members of these types are predominantly annual grass species of low nutritive value from the stand point of livestock nutrition. Constituent species are:

- Cenchrus biflorus
- Cenchrus ciliaris
- Eragrostis fremula
- E. aspera
- Aristida pallida

Cenchrus biflorus and Eragrostis species may serve as indicators of over-cultivation. This type provides the grazing of the two million Baggara cattle during the rainy season.

4. Exotheca Types (EX)

Exotheca is characteristic of the vegetation of the Imatong and Didanga Mountains in the altitude range of 1,400 to 3,000 metres. Important grass species of this type are:

- Exotheca abyssinica
- Digitaria uniglumus
- Setaria sphacelata

These species dominate a small part in the southern region of the country where rainfall is believed to be over 1,300 mm., distributed over about eight months from March to October.

5. Hyparrhenia Type (HY)

Hyparrhenia occurs in the South Western part of the Sudan, south of Bahr El Arab river and to the border with the Central African Republic. Common grass species are:

- Hyparrhenia dissoluta
- H. filipendula
- H. barters
- H. rufa

- Andropogon gayanus
- Ctenium elegans
- Sporobolus festivus
- Pennisetum purpureum
- Panicum maximum

H. ruffa occurs on soils with a high clay content and C. elegans and S. festivus are most common on shallow soils. P. purpureum and P. maximum are found most commonly on areas divided from forests by gulleys and streams. This type is associated with a woodland savannah of varying density of savannah tree species such as Anogeissus sp. and Khaya sp.

6. Sorghum Type (SO)

Sorghum dominates the area between the Blue Nile and Nahr Atbara river up to the border with Ethiopia. Common grass species are:

- Sorghum purpuco
- Hyparrhenia sp
- Cymbopogon nervatus

Species of this type occur in solid stands of treeless heavy clay soils. Among thick bush, grass species such as Tetrapogon spathaceus, Setaria verticillata, Rottboellia exaltata and Cenchrus ciliaris fare well and make a mix of stands with good grazing value. However, most of the areas where this grass type occurs cannot be used by cattle during the rainy season (June-September) because of the mud and biting fly irritation.

7. Undifferentiated Swamps (US)

Throughout the continent of Africa, there occur seasonal and perennial swamps which have been classified as 'Undifferentiated Swamps,' owing to the wide range of condition which prevail in these areas. These swamps are dominated by the sedge, grass-like species, together with other grass species. Common sedge and grass species are:

- Cyperus papyrus
- Echinochloa pyramidalis
- E. stagnina
- Brachiaria mufica
- Oryza barthii
- Typha sp.

8. Undifferentiated Mountain Vegetation (UM)

Areas of mountainous vegetation which occur due to elevation can be considered as a zone by themselves.

PRINCIPAL CAUSES OF DESERTIFICATION AND RELATIVE IMPORTANCE OF EACH CAUSE

Principal Causes

Desertification is the product of interaction of environmental parameters with unbalanced utilization of land by man. In the Sudano-Sahelian region, pastoralism is the most prominent type of land utilization. Misuse of rangelands and pastoral resources could be considered as the most important single cause of desertification. However, from the standpoint of range management, desertification can be attributed to the following misuses:

1. Conversion of rangelands into cereals cultivation;

2. Destruction of pastoral resources through fire;

3. Nomadic use and lack of grazing management;

   a. Increased livestock population
   b. Improper distribution of animals
   c. Improper timing of utilization

4. Overgrazing.

Conversion of Rangelands into Cereals Cultivation. As a result of population growth in the Sudan, man is becoming generally more concerned about providing for nutritional requirements. Consequently, more lands have been put under cultivation to meet the growing demand for food. A recent estimate has revealed that human population in the Sudan increased by four million during the period between 1956 to 1974. The rate of growth is estimated as 2.1 percent overall and 5 percent in urban areas. In semi-arid areas such as Northern Kordofan and Darfur Provinces, population growth has already outstripped the available land for agriculture. In the eagerness to grow more food, people in these areas have abandoned their traditional systems of crop rotation and have created shortages of land for new expansion. Recent increases in variability and uncertainty in rainfall have encouraged people to clear larger areas than before. After the rainy season, they decide which parts have received adequate rain to make their cultivation more fruitful. In this process, larger and larger parts of natural rangelands are lost due to erratic cropping systems which eventually cause desertification.

A point worth mentioning is that in 1961 the area under traditional cultivation of sesame and peanuts in Kordofan Province was 112,000 and 184,000 feddans,* respectively. In 1973 the area under these crops was estimated as 14,722 and 81,000 feddans, respectively. This fact can reasonably indicate

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* There are 2.4 feddans in one hectare.

that the proportion of rangelands under cereal crop production is declining, approximately in the order of 5:1 from 1961-1973, largely due to decreasing productivity.

Apart from the erratic expansion of cereal crop cultivation, rangelands in the Sudan are subject to conversion into cereal crop cultivation during every developmental plan in the agricultural sector. According to a 1981-1982 census, cultivated area in the Sudan is estimated as 15.2 million feddans or 1.3 percent of the total area of the country. Most of these areas were once productive rangelands that supported huge numbers of domestic and wild fauna. Subsequently, these huge numbers of livestock have been shifted to overstock and overgraze other and more marginal parts of the country.

It has been estimated that the area under rainfed mechanized farming which expands at the expense of rangelands amounts to nearly 6 million feddan and the proposed area for future expansion is estimated as 1.8 million feddan Table 1.3).

TABLE 1.3

PROPOSED EXPANSION OF RAINFED MECHANIZED FARMING

Area 000 fed.	Location
300	Northern, Upper Nile
600	Southern Kordofan
200	Kosti District
700	Damazin region
1,800	

SOURCE: Mechanized Farming Inc. (1982)

This proposed 1.8 million feddan for mechanized rainfed agriculture is phased according to the following schedule:

300,000 feddan for the season 1982-1983
400,000 feddan for the season 1983-1984
500,000 feddan for the season 1984-1985
600,000 feddan for the season 1985-1986

This indicates that rainfed mechanized agriculture alone cuts annually between 300,000 to 600,000 feddan from rangelands.

Destruction of Pastoral Resources through Fire. Most of the Sudanese rangelands and pastoral resources are located in the savannah ecosystem. Savannah is created and maintained by fire. So long as fires persist, they remain savannahs; when fire is controlled, they revert to woodlands (Stoddart, et al.

1975). Natural fire is an ecological factor in the Savannahs. Fire is no longer a natural ecological component. The higher frequency of man-made fire outbreaks has convertei fire into a destructive force. During the long dry season, most of the forage plant species dry up and become highly susceptible to burning. Wittingly or not, man sets uncontrolled fires and thus destroys his own natural resources.

The amount of forage lost annually due to seasonal fires is estimated as 307,892,380 tons for the whole country (Table 1.4). This amount constitutes about 30 percent of the natural grazing resources. It is difficult to survey all reasons and factors associated with grass fires in the Sudan. However, burning for land preparation, the hunting of wild animals, honey collecting, and tribal or individual grudges are among the main causes of these fires.

TABLE 1.4

AMOUNT OF FORAGE REMOVED BY SEASONAL FIRE

PROVINCE	TOTAL FORAGE PRODUCTION (TONS)	% OF FORAGE REMOVED	TOTAL FORAGE REMOVED (TONS)
Kordofan	112,252,800	30	33,675,840
Darfur	218,712,000	20	65,613,800
Kassala	31,567,000	20	61,313,400
Northern	-	-	-
Blue Nile	35,072,000	15	2,260,800
Khartoum	2,592,000	10	505,200
Upper Nile	67,045,400	35	23,466,240
Bahr el Ghazal	204,096,000	40	81,638,400
Equatoria	119,168,000	45	89,625,600
TOTAL	870,506,200		307,892,380

SOURCE: Range and Pasture Administration, Ministry of Agriculture, Food and Nat. Res. (1968)

Nomadic Use and Lack of Grazing Management. More than 85 percent of Sudan's livestock population is owned by nomads. Their transhumance is largely dictated by the need for water and forage. Thus far, nomadism in the Sudan works within the general framework of transhumance, as in other parts of the world. Detailed patterns and transhumance cycles in the Sudan have been studied by several authors (e.g., Barbour 1961). Most of the nomadic tribes use the same seasonal routes. They recognize and practice a sort of collective ownership of the pasture lands within their particular routes.

Nomadism as a form of land use and a special way of living is best exemplified by the nomads of Kordofan (Figure 1.3). The importance of nomadism in Kordofan province comes from the fact that camel owners (Kababish), cattle owners (Mesiriya and Hawazma), and sheep owners (Hamar) are all represented and

SEASONAL MOVEMENT OF NOMADS IN KORDOFAN PROVINCE

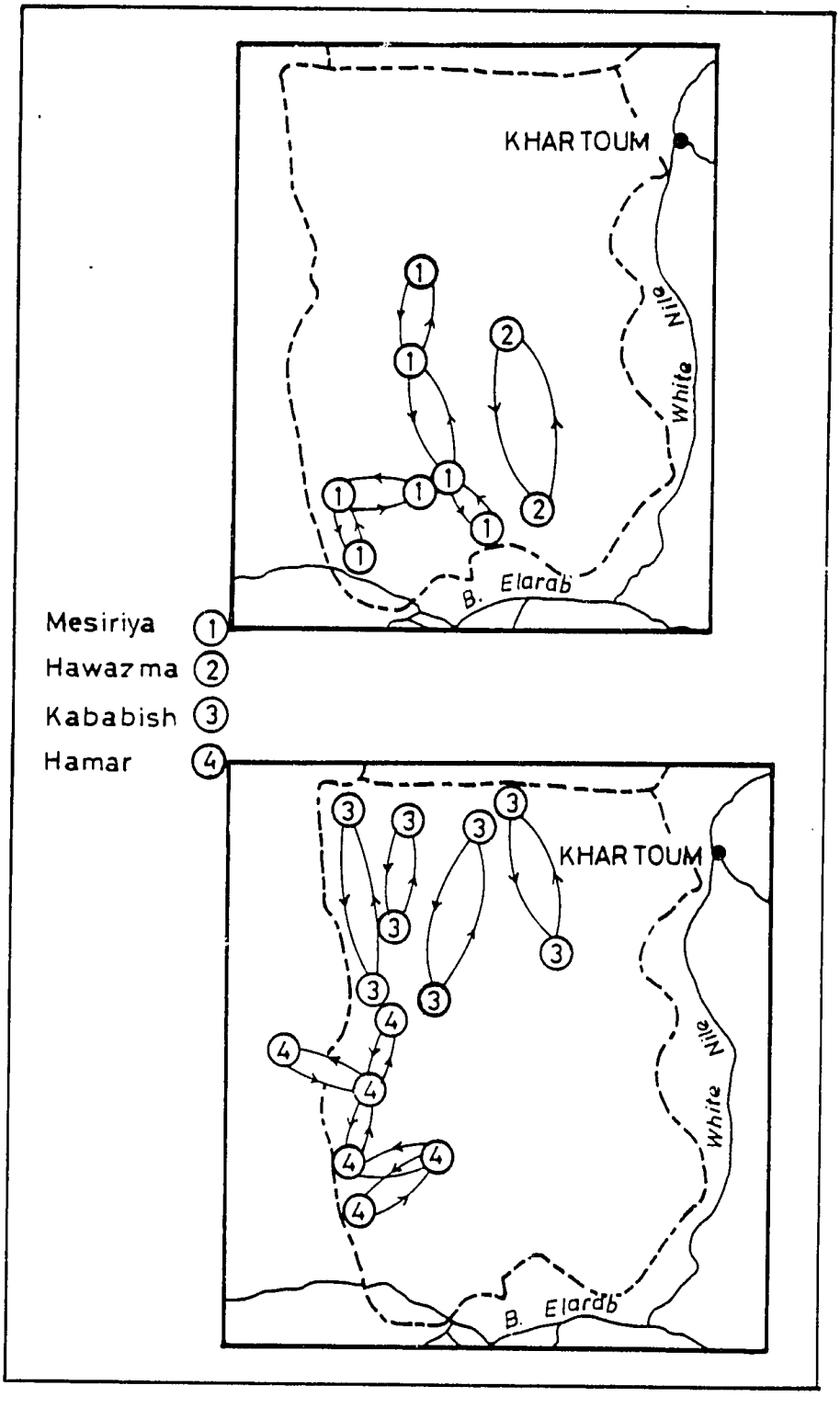


Figure 1.3

each tribe has its well defined and distinct transhumant route. Nomadic use of rangelands is considered to be an ideal way of utilizing the thin vegetative cover in arid and semi-arid areas and ecologically more sound than settlement (Darling and Farvar 1972, and Suliman 1977). However, there are some drawbacks associated with nomadism and nomadic use of rangelands in the Sudan, including increased livestock population beyond the carrying capacity, improper distribution of animals, and improper time of utilization.

Data pertaining to livestock population have long been considered as unreliable. All previous attempts were based wholly on crude estimations which are unlikely to be fair given the dynamic nature of the nomadic society. Crude figures obtained from the vaccination register, or 'Koshofat El Gutaan' (Livestock local government taxes) are really far below the actual number. Nomads are generally antagonistic toward vaccinating their animals and obviously when being taxed, nomads evade the truth about their property. Molbrook and Yust (1966) came out with more realistic figures. They also estimated the rates of annual increase for all kinds of livestock in the Sudan (Table 1.5).

TABLE 1.5

LIVESTOCK POPULATION IN THE SUDAN (1966)

ANIMALS	NO. IN (000)	RATE OF ANNUAL INCREASE %
Cattle	10,000	2.5
Sheep	10,000	3.0
Goats	7,000	2.86
Camels	2,500	.0

A recent estimate indicated that the national rate of increase between 1970-1977 was 3.7 percent for cattle, 4.3 percent for sheep, 5.7 percent for goats, and 2.25 percent for camels. Table 1.6 shows the estimated animal populations in the Sudan and the percentage of national herd in Kordofan and Darfur Provinces where severe desertification is taking place.

It is obvious that these increases are attributable to extended veterinary care, water provision, and factors related to the socioeconomic complex of the nomads, such as low annual off-take and lack of commercialization consciousness with regard to their herd. Unfortunately, these increases in livestock populations were always beyond the carrying capacity of the range and subsequently contributed to overgrazing.

Proper distribution of animals on the range is a cardinal principle of grazing management. Improper distribution results in patchy grazing that leads to overgrazing and expansion of desertified areas. In nomadic society, improper distribution is exemplified by the confinement of grazing activities to a fixed strip of transhumance route and concentration of huge numbers of animals around water points.

TABLE 1.6

ANIMAL POPULATIONS IN THE SUDAN AND THE PERCENTAGE OF NATIONAL HERD IN KORDOFAN AND DARFUR

ANIMALS	NO. IN THE NATION (000)	% IN KORDOFAN AND DARFUR
Cattle	15,367	40%
Sheep	16,230	33%
Goats	11,292	42%
Camels	2,361	52%

SOURCE: Estimates by Murray Watson, 1975-1976

Sporadic distribution of water in arid and semi-arid regions causes many range utilization problems, and results in denuded areas around watering points (Stoddard, et al. 1975). In the Sudan, areas around watering points have been completely denuded by high concentrations of animals. It has been reported (DECARP 1976) that most watering points serve as a nucleus for potential desertification. Uneven distribution of watering points and confinement of the nomadic grazing activities leave large areas of good grazing resources under--utilized. This normally burns off before the rainy season and further contributes to the retrogression of the natural resources.

Proper timing of utilization of forage plant species is also one of the four cardinal principles of grazing management. Proper time of utilization should match with the appropriate phenological stage of the plant grazed. Nomads in the Sudan do not bother with the proper time of grazing. In most cases they graze an area when plants are not ready for grazing. Sometimes they graze when the soil is too wet. This will eventually cause damage to both plants and soil.

Thousands and thousands of areas in the Baggara grazing domain have been denuded due to trampling of livestock during the early wet season. Moreover, most of the forage plant species have been eradicated because of early grazing before they complete their life span and deposit some seeds in the soil bank. This misuse will cause completely denuded areas that act as nuclei for potential desertification.

Overgrazing The combination of the above stated causes (conversion of rangelands into cereal cultivation; damages of rangelands by fire; and nomadic use including increased livestock population, improper distribution of animals and improper time of utilization) result in overgrazing of most of our rangelands. This is mainly attributed to the imbalance which exists between livestock population and the current grazing resource capacities. This imbalance is due to the increase of livestock population.

Apart from areas currently under cultivation (15.2 million feddans in 81/1982 census or 1.3 percent of total area) and areas not available for grazing or agriculture because of physical constraint (48.5 percent of total), the current available range and forest resources constitute only 279.4 million feddans (50.2 percent of the total area). The total seasonal forage produced from the usable rangeland in the country is illustrated in Table 1.7.

TABLE 1.7

ESTIMATED TOTAL FORAGE PRODUCTION

REGION	DOMINANT ECOLOGICAL ZONES	USABLE RANGELAND FEDDANS	AVERAGE FORAGE PRODUC-TION (TON/FEDD.)	TOTAL FORAGE (TON/DM.)
1. Northern	Desert & semi-desert	11,006,780	0.082	905,836
2. Eastern	Desert/semi-desert Low rainfall savannah	43,419,850	0.15	6,512,978
3. Middle	Semi-desert/Low & high rainfall savannah	15,148,920	0.64	9,695,309
4. Khartoum	Semi-desert	3,850,900	0.14	536,326
5. Kordofan	Desert/Semi-desert Low & high rainfall savannah and the flood region	53,502,370	0.27	14,445,639
6. Darfur	Desert/Semi-desert Low & high rainfall savannah	64,743,850	0.23	14,891,085
7. S. Region	High rainfall savannah Flood region and mountain vegetation	87,803,890	0.35	30,731,361
TOTAL		279,496,560		77,718,534

SOURCE: Halbrook and Yast (1964), and Range and Pasture Administration records (1979)

As Table 1.7 indicates, the total forage produced from the range amounts to 77.7 million tons which is equivalent to:

$$= 77.7 \times \frac{95}{100} \times \frac{31.4}{100} = 23.1 \text{ million ton (TDN)}$$

= if the annual requirement per animal unit (AU) is 1.0441 tons (TDN), then the total (AU) that can be supported by range = 22.1 million (AU).

The total existing livestock population (1980/1981) amounts to 27.7 million (AU).

This clearly indicates that the current livestock population (77.7 million AU) exceeds the population that can be supported by the available grazing resources (22.1 million AU) by almost 56 million (AU). This explains the problem of overgrazing. Figure 1.4 shows the interrelated causes of range deterioration and thereby outlines the processes of anthropogenic desertification.

MISUSES OF RANGELANDS AS RELATED TO DESERTIFICATION IN THE SUDAN

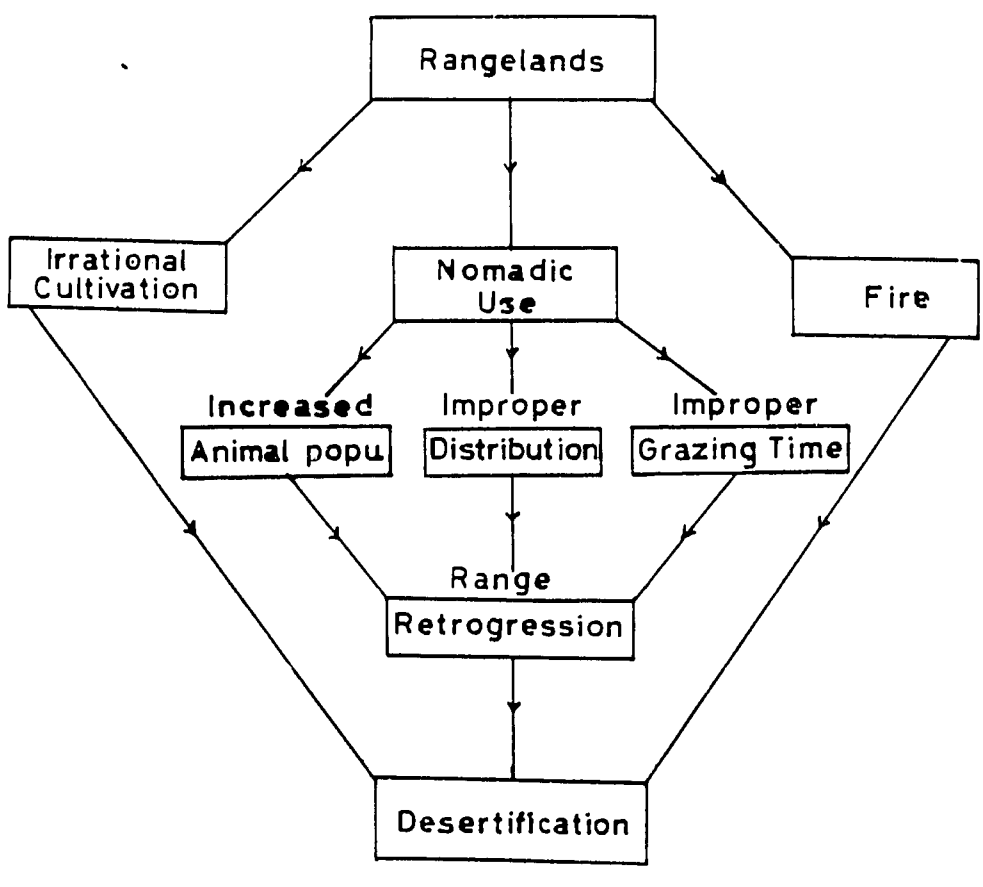


Figure 1.4

Relative Importance of Each Cause

As mentioned before, most of the work on desertification in the Sudan is not yet quantified. Actual measurement, experimentation, and monitoring should be carried out for all causes and effects of desertification. Due to lack of quantification, the relative importance of each cause can hardly be calculated. However, the importance of each cause can be estimated in the areas affected by desertification.

Severely Desertified Areas (Aristida grass cover type). The dominant grass species in Sudan's heavily desertified zones is Aristida. These species and their associates in this particular area are annuals. As the vegetation cover is thin in this area, the fuel is not enough to carry fire. The probability of fire outbreaks is very low.

Lack of grazing management is the most important cause of desertification for the heavily stressed areas. By virtue of its location at the fringe of the desert, these severely desertified areas are naturally very fragile and any slight imbalance such as increased livestock population and lack of grazing management, is disasterous. Given increases in both human and livestock populations since independence, the problem in the zone is becoming acute.

Moderately Desertified Areas. These include Cenchrus and Andropogon grass cover types. They constitute a considerable portion of low rainfall woodland savannah on sand. These areas are also described as "Qoz" regions where most of the Baggara cattle graze during the wet season.

The most important cause of desertification in this particular region is the improper distribution of water points. During the last twenty years these areas have witnessed a very high rate of expansion in water provision through the installation of new water points. These new water sources triggered a series of events that eventually resulted in desertification. Provision of new water points attracted villagers and some livestock owners to settle. The new settlers needed land for both grazing and millet cultivation, together with supplies of woody species for house building and fuel needs. Taken together, these activities quickly outstripped the land's regenerative capacities leading to severe desertification around water points.

Lightly Desertified Areas. These areas can be categorized into three subregions. The eastern where sorghum grass cover is dominant; the central where Andropogon and Hyparrhenia grass cover are dominant; and the western where Cenchrus and Andropogon types are dominant.

In the eastern part, expansion of rain-fed mechanized agriculture can be considered as the most important cause for desertification. This particular part has experienced the first cultivation and later mechanized farming in the country (e.g., Gedaref, Ghadambolia and Dally and Mazmoum schemes). In the central part, where Andropogon and Hyparrhenia grass cover types are dominant, fire can be considered as the most important cause for environmental degradation. The vegetation cover in these parts is always dense and residents use burning as a means for clearing, hunting, and other purposes. In the western part of these areas improper timing of grazing is the most prominent cause for

desertification. Cattle owners move early during the wet season from their summer grazing domain to where they can spend the wet season. In the move, they graze grass species at a very tender phenological stage. In the process they also trample the soil where it is wet and cause serious soil compaction. Fire becomes the most important factor in this region during their summer grazing activities. Where the grasses come back during the summer, higher fire outbreaks occur.

CORRECTIVE MEASURES AND INSTITUTIONS

Corrective Measures and Constraints

Increase off-take. The total off-take is low (7 percent for cattle and 25 percent for sheep) and is not comparable to the livestock population which exceeds 45 million head (80/81). Low extraction of stock is attributed to transport limitations because most of the purchased stock are driven on the hoof along the cattle route only during the rainy season when adequate water and grazing are available.

One of the solutions to solve this problem is the development of an infrastructure that will increase the off-take from the area of production to the main markets. For example, the IDA is currently financing a livestock marketing project (LMP). The total cost is estimated at US $51 million. At full operation and during the mid-eighties, 43,000 head of cattle and half a million head of sheep will be transported from the area of production to Omdurman and Port Sudan by rail. The project provides for livestock block train freight services, holding yards, transit yards, and terminal markets. This project will hopefully increase off-take by 20 percent for cattle and 30 percent for sheep by 1985 and up to 35 percent by 1990.

Water and grazing will also be made available along the traditional route to assist extraction of livestock from the area of production to the main markets during wet seasons (see Figure 1.3). Increasing off-take will help to regain the balance between the region's livestock population and the range resources.

Ranching Development. To solve the problem of over grazing, the Government also plans to establish sedentary and semi-sedentary grazing cooperatives where it is ecologically and physiologically feasible. They also plan to organize grazing districts, accompanied with the provision of grazing rights for individuals and tribes. An example of this plan is the 'Gereih el Sarha' project at Kababish District. Another example is the 'Gazala Gawazat' range research station which had been established to experiment on how settlement through ranching introduction can be achieved in the Reziegat District in Darfur Province. A third example is the I.D.B. Funded Western Savannah Development Project which by now is undergoing actual work in settlement in the Abu Gabra and Goz Dango areas through the establishment of ranching projects.

Integration of livestock with crop production. For sedentary populations, trials have to be started on how to integrate livestock within their present cropping system. This will require subtropical legumes to be incorporated in the cropping rotation to improve soil fertility and at the same time to produce new forage for livestock. Supplementary feed from crop residues and industrial by-products can also be used to balance feed requirements and to provide for fast fattening purposes. *Acacia senegal* can be used here as hedging to demarcate paddocks, to supply gum and feed, and to act as a shelter belt against wind erosion.

Management of grazing resources around permanent water supply centres. Permanent water supplies in arid areas become the focus of permanent settlements as well as centres to which livestock are brought from the surrounding areas on a regular basis for watering and grazing. Overgrazing around water points usually starts as a small circle but, as grazing pressures increase, the circle starts to enlarge. Here it must be mentioned that desertification is not a physical movement of the true desert from the north going south but is the creation of desert like condition *in situ* due to the misuse of grazing resources of the envelope surrounding these permanent water supply centres.

Efforts to reverse these patterns are demonstrated by the implementation of the range management practices around the permanent water supply project at Elodaya in Kordofan Province. This project was formulated and designed by the Range Management Administration as part of the overall programme to combat desertification in the Sudan. This project is now under implementation with funds provided by the United Nations Sudano-Sahelian office and the Sudan Government. Total cost allocated is almost 1.5 million Sudanese pounds, and the project is under implementation since the first of August, 1982. The project will contribute to restoring land productivity through improvement and systematic management of rangeland and contributing to the diversity and quality of agriculture and livestock production, thus promoting the area's overall economic and social development. In this project, all the physical work specified in the plans will be carried out by local communities. The project provides all materials needed for fencing, concrete for construction, seeds for seeding, etc.

Expansion of rainfed agriculture. In the past, shifting cultivation in the open savannah was an integral part of the dry farming system with a long period of fallow (5-10 years) to allow for regeneration of soil fertility. With the new expansion in water provision, shifting cultivation has given way to continuous cultivation in marginal lands which is now causing severe soil deterioration and desertification, especially in the northern part of the savannah belt.

The new strategy of the Government is to discourage rainfed cropping in marginal land where rainfall is less than 100 mm. The strategy also aims at implementation of integrated crop and forage legumes such as *Clitoria ternata* and *Philipesara* species in most of the newly proposed agricultural schemes. This plan is designed mainly to restore soil fertility and to produce enough feed for livestock. The availability of forage hay, crop residues, and agricultural by-products will assist the establishment of the feed lot system for the purpose of fattening livestock. Currently the Rahad project had been designed to accommodate the cultivation of forage legumes in the crop rotation

system. Cultivation of forage has not yet started in the Rahad scheme because of social and financial constraints.

Another example is the Savannah Project (Phase I & II) which has established detailed resource inventories and proposed pilot projects in Southern Darfur and, to a limited extent, in Kordofan Province. These activities have outlined the broad strategies aimed at integrated and ecologically planned crop farming, livestock, forestry, and range development systems. Traditional small farmers and pastoralists would benefit from the project. Since the ecological zones are marginal or unsuitable for large scale mechanized farming, the Savannah Project succeeded to exclude such practices from its strategies. The suggested pilot projects will use research information from appropriately located stations.

Here it must be added that currently most of the agricultural activities are confined to the low rainfall savannah belt which are at the same time considered the main source of grazing for livestock. This low rainfall belt represents 50.2 percent of the total area of the country (297.7 million feddans). As previously indicated, this area is becoming insufficient to support the grazing of the livestock population (45 million head). Therefore any expansion in agriculture in this area will be at the expense of the rangeland and will increase the problem of overgrazing. New expansion in agriculture must be restricted to the high rainfall and the flood region (45.5 percent of total), provided that the current constraints which limit its utilization are removed.

Inappropriate Distribution of Drinking Water. Water is the key factor to full use of land resources regardless of whether the land capabilities are suited for crops, pasture, or forest. All nomadic migration and movements in the western savannah are in fact organized in accordance with the availability of both drinking water and adequate grazing.

In the past, an attempt was undertaken to make water available and to solve problems of nomadic settlement. The Government, with good intention, has spent large sums of money on water development. The criterion used in water provision was based entirely upon the actual requirements of the human and animal population of the grazing region with no regard to the land capability, to the actual carrying capacity of the grazing resources, or to the current patterns of the nomadic migration and movements (Thirst in the Sudan: Facts and Figures, 1970). In this plan, water systems had been planned to supply 75 percent of the total deficit in addition to the amount needed to satisfy normal increases in both human and animal population. In 1970, about ten thousand water sites were installed where the geological formations permitted the easy installation of a deep bore system. These additional water sources shortened the distance separating the water points to less than ten kms. Since the radius of the grazing envelope surrounding water points usually exceeds eight kms., shortening the distance created an overlap of envelopes. The shortening in turn resulted in the expansion of overgrazing and soil deterioration of most areas that surround permanent water supply centers.

The only solution to this problem is finding ways to remove the heavy grazing pressure within the "easy" areas where "too much" water has been provided and to provide water in the "empty" areas (Basement complex) which at

present are not under heavy use because there are no watering points. Further, any solution must be fitted into the current pattern of seasonal movement. All this must be done in ways which provide for proper conservation, management, and improvement of natural resources.

It is now understood that the policy of developing unlimited water supply sources, regardless of the potential carrying capacity of the grazing resources or the current patterns of nomadic movements, has in fact led to overgrazing, soil deterioration, and finally, desertification. In the country's new program to combat desertification, new criteria have been adopted in the field of water provision and distribution. These are aimed at the integration of water provision activities with range conservation and management. In this new system, siting of new water is now coordinated with the carrying capacity of the range, and water points are used as an indirect means to direct the seasonal movements of nomadic tribes according to the condition of the grazing resources.

According to a special FAO Fund Project (1962-1965) the "empty" area constitutes more than 35 percent of the total area of the low rainfall savannah belt. These areas are not now fully utilized because of lack of water supply. The FAO Special Fund Project in Kordofan developed three types of catchment storage tanks during the experimentation phase of the project. The essential elements of the construction were: (1) the excavation of an 'Hafir'; (2) lining with an impermeable layer; and, (3) covering with a roof structure made of a reinforced concrete. The impervious lining used to prevent seepage was mainly a multiple 'sandwhich' of fine gauge polyethylene and clay. The structure successfully trapped and stored water in these areas but the termites damaged the polythelene. The investigations along this line must continue until a suitable lining material is found.

Fire Lining System. Seasonal fires were identified as one of the most influential factors causing deterioration of the grazing resources and desertification. Seasonal fires are either due to carelessness of nomadic tribes or to "harig" cultivation practices in dry farming. Studies undertaken by the Range and Pasture Administration (1968) proved that seasonal fires annually remove not less than 35 percent of the total annual forage produced (See Table 1.4).

Of course, it can be argued that periodic burning is a principal factor in maintaining the open aspect of the current typical savannah formation. But continuous repeated burning, besides destroying soil protective vegetation cover also induces remarkable change in the floristic composition, allows the invasion of undesirable fire resistant annuals which offer very little environmental protection. The ecological studies conducted by the Range and Pasture Administration since 1958 and those carried out by the Kordofan Special Fund project (1962-1965) indicated that more than 60 percent of the current floristic composition of the savannah vegetation is predominantly annuals, and the desirable perennial grasses which are vulnerable to repeated burning are in the process of being replaced by less desirable fire resistant annual grasses.

The Government recently started a fire prevention project for conserving the currently used grazing land in the savannah belt. In this project a grid of fire lines eighty metres wide is seasonally built immediately after the rainy season, using local hand tools. The total length of the grid is about

12,800 kms. It has been planned to extend the total length of the grid to reach 28,800 kms. by the end of the six-year development plan (1984).

The opening of the fire lines is still being done by hand implements at a cost ranging from £S 8 - 10 per mile (US $7 - 9). The method is very slow, expensive and, above all does not give complete burning of the line, especially when the vegetation remains green for a period towards the end of the rainy season, and when understory stand is sparsely distributed which does not permit a thorough burning effect.

Experimentation to find practical and economically feasible methods and techniques for the construction of these fire lines is underway. Recently, the Range and Pasture Administration carried out experiments using three different chemicals in fire line building. Experimentation is still in progress to test economically feasible ways to use chemicals in fire line building.

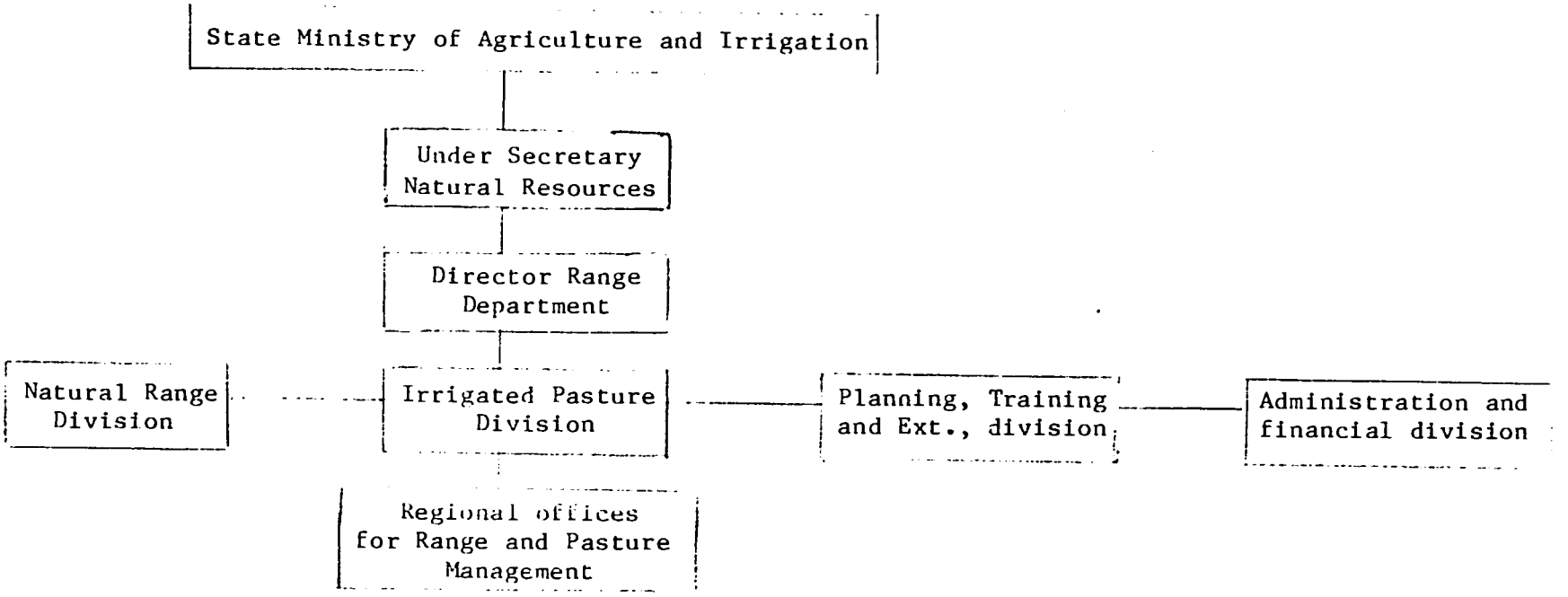
INSTITUTIONS CARRYING OUT CORRECTIVE MEASURES

The Ministry of Agriculture and Irrigation has been designated as the agency responsible for developing, coordinating, and evaluating the nation's natural resources including the grazing resources. Within the Ministry, the State Minister for Agriculture and Irrigation is the functional supervisor for three major departments, one of which is the Department of Range and Pasture Management. Range conservation, management, and improvement activities fall within the terms of reference assigned to the Department of Range and Pasture Management. The structure of the organization of the Range Management department at the headquarters level is shown on the following page (Table 1.8) and the number of personnel in natural resource conservation (Table 1.9) is shown on the following pages.

The Department's regional and provincial offices are well established all over the six major regions of northern Sudan. The major responsibility of the regional offices is the practical implementation of the Department's activities in the field of range inventory and evaluation, range conservation, management, range improvement, and desertification control. The regional offices are actually the linkage between the local and central authorities during policy making and project formulation pertaining to range management and improvement. All responsibilities pertaining to the practical implementation of range rehabilitation, conservation, and improvement measures are fully rested upon the Department's regional and provincial offices.

TABLE 1.8

RANGE AND PASTURE ADMINISTRATION HQ/STRUCTURE



NOTE: Working staff in the field of Natural Resources conservation and improvement is in Table No. (6).

TABLE 1.9

WORKING STAFF IN NATURAL RESOURCES CONSERVATION

SPECIALIZATION	GRADUATE SPECIALISTS	TECHNICAL ASSISTANTS	TOTAL
Range & Pasture Administration	68	97	165
Social Survey Department	210	90	300
Forest Department	30	150	180
Hydrology	40	20	60
Water Provision Experts			
Meteorological Specialist	23	110	133
Sourcers (Topography)	97	30	127
Geological Survey	102	50	152
Veterinarian	60	30	90
Agr. Administrators and Tech.	491	295	786
Vet. Administrators and Tech.	252	250	502
Faculty of Agr. Administrators	50	25	75
Faculty of Vet. Administrators	45	20	65
Agr. & Vet. Institutes	25	10	35
Irrigation Specialists	30	20	50
Ag. Specialists	131	380	481
Socioeconomic Specialists	34	7	41
Wildlife Experts	9	48	57
T O T A L	1867	1762	3629

NOTE: The current existing staff is not sufficient to cope with the proposed programme to combat desertification including range conservation and improvement.

CHAPTER TWO

Chapter two considers the problem of Sudan's declining national energy supply. Beginning with a national survey of energy production and use the chapter focuses on rural energy use as a major contributor to the desertification process.

Biomass in the form of woodfuel accounts for more than 95 percent of all energy consumption in rural households. The demand for fuelwood per capita is projected to decrease over the next decade, but with population growth the actual quantity of biomass needed to meet demand will continue to increase. The impact of continued harvesting of wood -- especially wood used to produce charcoal -- can only have a deleterious effect on Sudan's vegetative cover and exacerbate the desertification process. The author argues that the need for intervention in the form of afforestation projects to increase biomass availability is urgent and that improved technologies to increase efficiency (about 95 percent of the energy produced by the burning of wood is lost) is critical.

Other energy sources will continue to be developed in the Sudan. Hydropower and petroleum resources are currently under development. Solar and wind energy options are being explored. Other biomass sources such as the fermentation of molasses into ethanol or the use of groundnut shells as energy to produce charcoal are also under development. Nonetheless, woodfuel will remain the backbone of the Sudanese energy supply for some years to come.

Decreasing Energy Availability in Sudan with Particular Consideration on Rural Energy Supply

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INTRODUCTION

Until recent times, Sudan depended exclusively on traditional sources of energy. Biomass, in the form of woodfuel, agricultural residue, and animal dung were the sole sources of energy for household consumption. Solar energy was used directly for drying agricultural crops and mud bricks. Animals and wind driven boats were the only means of transport and animals provided the only available power for lifting water from rivers for drinking and irrigation. Sunshine, moon light, and vegetable oil fueled lamps were the main sources of light.

Modern sources of energy, like petroleum products and electricity were introduced in the country at the dawn of the twentieth century. The first river steamers in Sudan arrived in 1898 and were run by woodfuel until late in the fifties when they were replaced by oil-fueled steamers. Sudan's railway trains ran on coal and coke up to the late fifties when diesel engines took over. The first public electric generating station, with 300 K.W. capacity was installed in Khartoum in 1908 and was run on steam generated by woodfuel. The use of trucks as a means of road transport began to expand late in the thirties. The use of modern technologies consuming commercial energy, particularly in the fields of transport, services, industry, households and agriculture, began to take shape after the Second World War.

Before 1945, imports of coal, coke and oil products did not exceed 225,000 T.O.E. (oil ton equivalents) annually, amounting to not more than £S 2.4 million. After 1945, the imports of commercial energy in the form of oil products increased in both volume and value to reach 330,000 T.O.E. in 1950, costing £S 3.5 million. Ten years later, in 1960, the volume of imported energy reached 435,000 T.O.E. valued then at £S 4.1 million. By 1970, the demand for oil products reached one million tons and cost more than ten million Sudanese pounds.

Electric generation has developed enormously since the beginning of the century. Since 1908, many thermal stations were installed in the different regions of the country to bring the total capacity in 1980 to 165 M.W. Added to this capacity are at least 100 M.W. of self-generation facilities in many factories scattered all over the country. Hydropower started as early as 1962 when the Sennar Station began operating on the Sennar Dam with a capacity of 15 M.W. This was followed by the Girba Station in 1963 which has a capacity of 9.4 M.W. and later by the Damazine Station with a capacity of 130 M.W. Soon after these stations came into operation, two national grids were established: the Blue Nile grid comprising the hydropower stations of Damazine and Sennar connected with Medani Diesel Station (6 M.W.); Buri steam and diesel stations (60 M.W.) and Kilo 10 gas station (15 M.W.) with a total capacity of 226 M.W. in 1980; and the Eastern Grid comprising the hydropower station of Girba (9.4 M.W.) and diesel station (3.6 M.W.).

While commercial energy was being introduced, organization of natural energy resources began. The Forests Department was established in 1904 to procure wood for fuel, construction, and other industrial uses on a sustained yield basis as well as to protect the natural forests for soil and water conservation, wildlife habitat, and scenic and hygenic purposes. To achieve these

objectives, forestry laws and ordinances regulating tree cutting practises, movement and transportation of wood from forest-rich areas to drier areas, control of charcoal burning, and price controls were issued and enforced. Afforestation programmes to enrich the forestry resource and to meet future requirements of wood were also planned. Meanwhile, the government encouraged the importation of the then cheap kerosene as a substitute for woodfuel, particularly in northern, western and eastern parts of Sudan.

Planning for natural energy resources, whether hydro or wood, went on smoothly for some time. This planning process did not, however, consider other natural resources such as oil and gas since there was no serious programme of exploration in Sudan's early years. During the late fifties and early in the sixties Sudan started very ambitious development plans, particularly in the fields of irrigated and mechanized agriculture. These plans boosted the consumption of commercial energy. Late in the sixties and early seventies Sudan's development continued and branched out to development of roads, transport, industry, and public services. The demand for commercial energy began to accelerate rapidly. The 1973/74 oil crises and resultant increase in oil prices caught Sudan deeply involved in a wide spectrum of energy demanding projects. This situation, coupled with increased prices of capital goods for the unfinished development projects and low prices for Sudan's exported goods, greatly affected the economic position of the country. As a result, the oil bills in the last few years have consumed almost all of Sudan's foreign currency earnings from exported goods. Even with such high imports, there are still shortages of fuel. Woodfuel is also becoming scarce and costly.

To get a better understanding of the current use of energy by economic sectors and regions, and to assess future demand, the government conducted a nationwide energy survey (March 1981-September 1982). The findings of this energy survey are summarized in the following sections.

SUDAN ENERGY CONSUMPTION PATTERNS

The total energy consumption of Sudan in 1980 (the year taken as a base for the study), was estimated to be 6.997 million tons of oil equivalent (T.O.E.). With a population of 18.68 million, the per capita average consumption was 0.375 T.O.E. Compared with world average consumption of more than 5.0 T.O.E., Sudan is one of the least energy consuming countries in the world. The total amount of energy consumed by the different economic sectors was:

TABLE 2.1

ENERGY CONSUMPTION BY SECTOR

Sector	Percentage	T.O.E. (rounded)
Household	80.74%	5,650,000
Transport	8.15%	570,000
Industry (including electric generation, construction, and exploration)	6.31%	440,000
Services	3.22%	225,000
Agriculture	1.58%	110,000
TOTAL	100.00%	6,995,000

The household sector was the major energy consuming sector and derived its 5,649,650 T.O.E. from the firewood (3,366,900 T.O.E. or 94.21 percent of the total firewood), charcoal (1,763,300 T.O.E. or 94.73 percent of total charcoal), and other biomass (411,100 T.O.E. or 82.70 percent of total).

Biomass, therefore, supplied the household sector with 5,541,300 T.O.E. which was 98.08 percent of its total household energy requirement and 93.28 percent of the total biomass as used energy. This fact reflects the great dependence of the household sector on biomass. The balance of 1.92 percent of household energy requirement was met, nearly equally, by oil products and electricity.

Oil products in the form of L.P.G., kerosene and gas oil accounted for 54,300 T.O.E. or 5.4 percent of the total oil consumed. Electricity generated by hydro-power and thermally produced 53,450 T.O.E. or 37.5 percent of the electricity generated nationally. When compared to the total consumption of energy for the household sector, however, electricity contributes only 0.95 percent of all energy used.

The second most energy consuming sector was the transportation sector. Here only one source of energy (excluding animal power) was used. Oil products in the form of gas, oil, benzene, aviation fuel, kerosene and furnace oil were consumed in the total amount of 570,600 T.O.E. This was 57.48 percent of the total oil consumed in the country and 8.15 percent of the total energy consumed nationally. The pattern of consumption in 1980 for the transportation sector was: 296,200 T.O.E. of gas and oil or 29.83 percent of all oil products used nationally; 207,000 T.O.E. of benzene and aviation fuel accounting for 20.85 percent of total oil used; 46,800 T.O.E. of kerosene which comprised 4.7 percent of total oil used; and 20,600 T.O.E. of furnace oil account for only 2.1 percent of all oil used.

TABLE 2.2

BREAKDOWN OF TOTAL ENERGY CONSUMPTION, BY SOURCE

BIOMASS			
A. Woodfuel			
1. Firewood	3,573,800 T.O.E.	or	51.07% of TOTAL
2. Charcoal	1,861,300 T.O.E.	or	26.60% of TOTAL
SUBTOTAL	5,435,100 T.O.E.	or	77.67% of TOTAL
B. Other biomass	505,600 T.O.E.	or	7.23% of TOTAL
TOTAL BIOMASS. . .	5,940,700 T.O.E.	or	84.90% of TOTAL
OIL	992,800 T.O.E.	or	14.19% of TOTAL
HYDROPOWER:	63,500 T.O.E.	or	0.91% of TOTAL
GRAND TOTAL	6,997,000 T.O.E.	or	100.00% of TOTAL

The third highest consumer in 1980 was the industrial sector, including construction and exploration activities. This sector derived its energy requirements mainly from oil products, either as direct fuel or for generation of electricity. It depended to a lesser extent on electricity generated by hydropower and on biomass. Out of 425,866 T.O.E. consumed by this sector, oil products contributed 185,891 T.O.E. or 58.67 percent of its requirement. This amount is nearly 18.92 percent of the total quantity of oil consumed in the country. Furnace oil, gas oil and diesel were the main oil products consumed by this sector.

Electricity generated thermally consumed 78,100 T.O.E. of the oil products allotted to the industrial sector. Total electricity generated in the country from both oil and hydro resources contributed the equivalent of 141,600 T.O.E. or nearly 2.02 percent of the total energy resource available. The amount of electricity consumed by the industrial sector in 1980 amounted to 49,566 T.O.E. or almost 11.64 percent of the sector requirement from energy and 35 percent of the total electricity generated. Biomass, in the form of wood, baggasse and other agricultural residues contributed by 190,400 T.O.E. to this sector.

The fourth energy consuming sector, in 1980, was the services sector. Here 268,204 T.O.E. or 3.83 percent of the total energy was consumed. This sector took its energy supplies mainly from biomass where 209,000 T.O.E. or 77.93 percent of the sector's requirement was met by firewood and charcoal for such services as laundry, restaurants and hotels. Oil contribution in the form of L.P.G. and gasoline was in the magnitude of 49,133 T.O.E.

The last sector in the rating of energy consumption in 1980, was the agricultural sector. A total amount of 110,629 T.O.E. was consumed by this sector. This sector mainly used oil which supplied 103,396 T.O.E. or nearly 93.56 percent of the sector's requirement. Electricity generated both by hydro and thermal fuels supplied the balance of the sector requirement. Table 2.3 shows the dependence of each economic sector on the different energy sources, expressed as a percentage of the total sector energy requirement as in 1980.

Reflecting on these findings, one can see the important role of biomass in the Sudan energy balance now and the need to conserve its resources for many years to come. Conservation steps need to be taken now, before the demands for oil and hydropower accelerate to such high levels that biomass cannot be used as a suitable substitute. The oil contribution of about 14 percent is too small and calls for active exploration work to bridge the gap that future demands will create. As for hydropower, its contribution is not only too small but is negligible if the total hydro-potential of the country is considered.

Regionally, the total energy consumption and distribution in Sudan in 1980 was:

Southern Region. The total energy consumption in this region amounted to 1,808,025 T.O.E. or 25.84 percent of the total energy consumed in the country. As this region is remote, less developed, and rich in forests, biomass in the form of wood, charcoal, and other agricultural residues contributed 98.90 percent of its energy requirement. Petroleum products contributed the balance of 1.10 percent. The hydropower potential in this region is not used and electricity generated thermally from oil products did not contribute more than 0.002 percent of the region's total energy requirement. Oil products are mainly consumed in this region by the transport and agricultural sectors who used 10,500 T.O.E. and 5,100 T.O.E., respectively. Consumption of oil in both industry and services sectors did not exceed 1900 T.O.E. in 1980. Table 2.4 shows the amounts of energy consumed by the different sectors in the Southern region for the year 1980.

The Central Region. This region consumed 1,636,499 T.O.E. or 23.39 percent of the total energy consumed in the country. Biomass contributed 82.75 percent, petroleum contributed 13.38 percent and hydropower contributed 3.87 percent. The electricity generated both by hydro and thermal power contributed 4.99 percent of the total regional energy requirement and amounted to 81,573 T.O.E. This region is the most populated region in the country. With 4,763,000 people living in it, it supports 25.5 percent of Sudan's total population. Unlike the Southern region, the Central region's consumption of energy in the sectors of transport, industry, services, and agriculture constitute more than 22 percent of the total energy consumed. Oil and electricity are used more particularly in the service and industrial sectors. Although this region has most of the

TABLE 2.3

DEPENDENCE OF THE ECONOMIC SECTORS ON ENERGY SOURCES

EXPRESSED AS A PERCENTAGE OF THE TOTAL SECTOR ENERGY REQUIREMENT

AS IN THE YEAR 1980

	HOUSEHOLDS	TRANSPORT	INDUSTRY	SERVICES	AGRICULTURE	ALL SECTORS
Biomass	98.09	-	47.78	77.93	-	84.90
Oil	1.48	100.00	46.65	18.32	93.46	14.19
Hydropower	0.43	-	5.57	3.75	6.54	00.91
TOTAL DEPENDENCY	100.00	100.00	100.00	100.00	100.00	100.00

SOURCE: Sudan Energy Assessment Work 1981/82

TABLE 2.4

SOUTHERN REGION ENERGY CONSUMPTION BY ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	1788	96.70	-	-	10.00	0.56	49.00	2.74	-	-	1788.00	98.89
Oil	2.2	11.22	10.50	53.57	———	4.60	1.00	5.10	5.00	25.51	19.60	1.09
Electricity (oil generated)	0.25	64.44	-	-	-	-	1.14	35.56	-	-	0.39	0.02
TOTAL SECTOR CONSUMPTION	1791.45	95.77	10.50	0.48	10.90	0.60	50.14	2.77	5.00	0.38	1808.00	100.00

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1981/82

major irrigated and mechanized agricultural schemes, energy consumption in the agricultural sector did not exceed 23 percent of oil products available to the region and not more than 25 percent of the generated electricity. Table 2.5 shows the central region's consumption of energy by economic sectors in 1980.

Darfur Region. This region is similar to the Southern region in its energy consumption patterns. Biomass contributed almost 98 percent of the total energy consumed in the region in 1980. The small percentage of oil consumed was mainly for transport and lighting. (See Table 2.6).

Kordofan Region. In this region, like Darfur and the Southern regions, biomass contributed more than 95 percent of the total energy consumed. Oil and electricity, generated by oil, did not contribute more than 4 percent of the total energy. Households consumed about 90 percent of the total energy in the Kordofan region, industry 2.3 percent, and agriculture less than 0.5 percent. Most of the oil products were consumed by the transport and household sectors. (See Table 2.7).

Eastern Region. This region, being adjacent to the Red Sea and Port Sudan, has more access to oil products than the other regions. Accordingly the volume of oil products consumed in the region was more than 23 percent of the total energy used in 1980. Most of the Northern, Eastern and Western parts of this region are arid, therefore biomass is rather scarce and contributed only 76.4 percent of the total regional energy requirement of 1980. Table 2.8 gives a summary of the region's energy consumption by sectors in 1980.

Khartoum Province. Like the Eastern region, Khartoum province is poor in biomass resources. It is also well connected by roads and the railway system to the Sea Port which facilitates the flow of oil products. Khartoum province is served by the Blue Nile electricity grid. These facts made Khartoum province less dependent on biomass than the other regions. In 1980 biomass contributed about 45 percent of the province's total energy requirement, while oil products contributed about 50 percent and electricity contributed about 5 percent of the total 1980 energy requirement (Table 2.9).

Northern Region. This region is the poorest of the regions in energy resources. The per capita consumption in 1980 was only 0.285 T.O.E. as compared to the national average of 0.375 T.O.E. Biomass, in the form of wood and charcoal, is imported from other regions or taken from the desert scrub. It constituted 74.25 percent of the total energy consumed in 1980. The use of oil (25 percent of the total energy consumed) was high compared to the other regions. The use of electricity was less than 0.7 percent of the total energy consumed. Table 2.10 summarizes the amount of energy consumed by sectors in this region in 1980.

Energy consumption, as stated above, is not evenly distributed among all regions of the country. The South and Khartoum province have the highest consumption per capita of energy, 0.434 T.O.E. in the South and 0.406 T.O.E. in Khartoum. The Eastern and Northern regions have the lowest per capita consumption, 0.325 T.O.E. in the Eastern regions and 0.285 T.O.E. in the Northern region.

TABLE 2.5

CENTRAL REGION ENERGY CONSUMPTION BY THE ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	1252.09	93.46	-	-	67.03	4.95	22.34	1.65	-	-	1354.20	82.75
Oil	12.35	5.64	85.67	40.86	60.85	27.79	6.17	_.82	50.12	22.89	218.96	13.36
Electricity (oil and hydro generated)	0.51	13.17	-	-	1.99	51.43	0.41	10.55	0.96	24.85	63.34	3.87
TOTAL SECTOR CONSUMPTION	1264.95	77.50	89.47	5.47	29.87	7.94	78.92	1.77	51.08	3.12	1636.50	100.00

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1981/82

TABLE 2.6

DARFUR REGION ENERGY CONSUMPTION BY THE ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	923.79	54.86	-	-	11.46	1.20	38.54	3.94	-	-	973.79	97.88
Oil	3.60	22.32	9.20	37.04	0.50	3.09	0.98	6.08	1.85	11.47	16.13	2.07
Electricity (oil generated)	2.31	46.55	-	-	0.60	12.07	2.06	41.38	-	-	4.57	0.005
TOTAL SECTOR CONSUMPTION	929.70	93.44	9.20	0.90	12.56	1.3	41.58	4.18	1.85	0.18	994.89	

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1981/82

TABLE 2.7

KORDOFAN REGION ENERGY CONSUMPTION BY ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	842.08	92.40	-	-	20.41	2.24	48.85	5.36	-	-	911.34	96.54
Oil	7.51	23.39	17.81	55.48	1.87	5.83	0.35	1.11	4.56	14.19	32.10	3.40
Electricity (oil generated)	0.36	64.52	-	-	-	-	0.20	35.48	-	-	0.56	0.06
TOTAL SECTOR CONSUMPTION	849.95	90.04	17.81	1.89	22.28	2.36	49.50	5.29	4.56	0.47	944.00	100.00

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1981/82

TABLE 2.8

EASTERN REGION ENERGY CONSUMPTION BY ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	469.10	90.78	-	-	26.25	9.08	21.38	4.14	-	-	516.73	76.44
Oil	10.94	6.95	78.88	50.10	13.68	8.69	27.84	17.68	26.10	16.58	157.44	23.29
Electricity (oil and hydro generated)	0.75	41.24	-	-	0.32	17.53	0.58	31.75	0.18	9.48	1.83	0.27
TOTAL SECTOR CONSUMPTION	480.79	71.12	78.88	11.67	40.25	5.95	49.80	7.37	26.28	3.89	676.00	100.00

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1981/82

TABLE 2.9

KHARTOUM PROVINCE ENERGY CONSUMPTION BY ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	248.34	89.11	-	-	29.35	10.08	14.10	4.83	-	-	291.79	44.89
Oil	12.68	3.84	279.66	84.58	35.56	10.91	0.39	0.12	1.62	0.55	325.91	50.14
Electricity (oil and hydro generated)	16.36	50.65	-	-	9.26	30.53	4.76	14.74	1.38	4.08	32.30	4.97
TOTAL SECTOR CONSUMPTION	277.38	42.68	275.66	42.41	74.77	11.50	19.25	2.96	3.00	0.45	650.00	100.00

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1 81/82

TABLE 2.10

NORTHERN REGION ENERGY CONSUMPTION BY ECONOMIC SECTORS - 1980

	HOUSEHOLDS		TRANSPORT		INDUSTRY		SERVICES		AGRICULTURE		TOTAL SOURCE CONSUMPTION	
	Quantity T.O.E. (000)	% of Total Energy	Q	%	Q	%	Q	%	Q	%	Q	%
Biomass	191.92	89.75	-	-	7.74	3.62	14.18	6.63	-	-	213.84	74.25
Oil	1.49	2.06	30.80	42.67	6.98	37.39	1.26	1.75	11.70	16.13	72.17	25.06
Electricity (oil generated)	1.00	50.00	-	-	0.03	1.77	0.80	40.27	0.16	7.96	1.99	0.69
TOTAL SECTOR CONSUMPTION	194.41	67.50	30.80	10.69	4.75	12.07	16.24	5.64	11.86	4.10	288.00	100.00

Q = Quantity

% = % of Total Energy

SOURCE: Sudan Energy Assessment Work 1981/82

Khartoum, Northern and Eastern regions have a higher dependency on oil than the other regions. Darfur region, the Southern region and Kordofan region have the least electrical capacity in the country.

Table 2.12 page 44) illustrates the total energy consumed in Sudan by regions. As can be seen in this table and in Table 2.3, biomass is the major source of energy in the country. Although it constitutes about 85 percent of the total energy consumed, the actual energy efficiency realized from biomass is small. Wood, directly burnt, only offers 3 to 6 percent of its energy as the rest is dissipated through the inefficient use of open fires and stoves. The maximum energy obtained from charcoal, with the stoves used in Sudan, is less than 15 percent. Therefore, the actual contribution of biomass is not more than 425,000 T.O.E. or 28 to 29 percent of the total energy utilized.

FUTURE ENERGY REQUIREMENTS

From the 1981-82 energy survey, it can be seen that the commercial sector is increasing its use of petroleum products and electricity, and decreasing its percentage use of biomass.

The population of the country is expected to increase at the rate of 2.5 to 2.8 percent in the next ten years. Increase in demand for oil products is expected to be in the range of 11 percent annually for benzene, 6 percent for gas oil, and 5 percent for furnace oil with an overall average of 8 percent for all oil products. The demand for electricity is expected to increase in the range of 11-15 percent annually.

Per capita, the demand for woodfuel is expected to fall at an annual rate of 2.2 percent. However the total amount of woodfuel required to meet the demand of the increasing population will be increasing annually by not less than 0.4 percent. The amount of energy requirement in 1985 and 1990 as compared to 1980 requirements is shown below (Table 2.11).

TABLE 2.11

	1980	1985	1990
		(in thousands T.O.E.)	
Biomass	5,940.7	6,155.0	6,620.0
Oil	992.8	1,460.0	2,150.0
Electricity (hydro and thermal)	141.6	240	406

The amount of woodfuel obtained in 1980 was more than the legally allowable amount to be cut from the forestry resource, exacerbating desertification in the Northern Region. Woodfuel removed in 1980 totalled more than ten million tons and was mainly obtained from the Southern, Central, Darfur, Eastern, and Kordofan Regions. As mentioned earlier, much of the energy of this fuel is

TABLE 2.12

ENERGY CONSUMPTION BY REGIONS - 1980

REGION	POPULATION (000)	% OF TOTAL POPULATION	TOTAL ENERGY CONSUMPTION T.O.E. (000)	PER CAPITA CONSUMPTION T.O.E.	% OF TOTAL ENERGY CONSUMED	CONTRIBUTION OF DIFFERENT SOURCES OF ENERGY AS PERCENTAGE OF TOTAL ENERGY				
						BIOMASS	OIL	HYDRO	TOTAL	TOTAL ELECTRICITY GENERATED HYDRO THERMAL
SOUTHERN	4.163	22.28	1808	0.434	25.85	98.899	1.099	-	100.00	0.020
CENTRAL	4.763	25.50	1636	0.378	23.38	82.75	13.36	3.87	100.00	3.870
DARFUR	2.620	14.03	995	0.380	14.22	97.88	2.07	-	100.00	0.005
KORDOFAN	2.442	13.07	944	0.387	13.49	96.54	3.46	-	100.00	0.060
EASTERN	2082	11.15	676	0.325	9.66	76.44	23.29	0.27	100.00	0.270
KHARTOUM	1.600	8.57	650	0.406	9.29	44.89	55.11	-	100.00	4.970
NORTHERN	1.010	5.40	288	0.285	4.12	74.25	25.75	-	100.00	0.690
SUDAN	18680	100.00	6997	0.375	100.00	84.90	14.19	0.91	100.00	2.020

lost through inefficient use. If the wood resource was converted to charcoal in a more eficient way and the methods for burning wood and charcoal were more efficient, then half of the wood available now could take care of the woodfuel demand until 1990.

Other biomass, in the form of agricultural residues, is produced annually at a rate exceeding 3 million tons. To date, these other biomass sources are not used much. The sugar factories can produce more than 200,000 tons of molasses when operating of full capacity. They can also produce more than 40,000 tons of ethanol, which can replace benzene. Ethanol could substitute for about 13 percent of the benzene consumption by 1990. Other agricultural residues, such as ground nut shells and dura stalks can be densified and used as substitutes for firewood, particularly in small rural industries such as bakeries, pottery, tobacco curing, and red brick production. Afforestation programs, now very meager and not exceeding 7,000 feddan annually, can be boosted to bridge an ever widening gap in woodfuel requirements.

Exploration activities for oil and gas have been intensified since 1976 and some discoveries have been made. Oil consumption patterns need to be studied to develop feasible methods of reducing the large amount of waste that now exists. Energy conservation and efficient use of oil products in industry, agriculture, and transport are paramount. The hydro power potential in Sudan is estimated to exceed 3,700 M.W. though it is unevenly distributed. Not more than 4 percent of this potential is currently being used; plans for future use are under study. The Nile Water Plan is being revised to promote energy projects and small hydropower units are being studied to provide the main source of power for rural development.

Solar and wind energy are also being considered for future development, particularly for water pumping and electricity generation in remote areas of western and northern Sudan. Although it may take some time to convert to these power sources, work on their development has actually started in the country. The Ministry of Energy and Mining together with the National Council of Research are conducting studies on renewable energy resources and their future applications. These studies will include the application of solar and wind energy in human settlement, agriculture, and industry.

The Ministry of Energy and Mining is undertaking a large and extensive programme to formulate policies and plans to secure adequate energy supplies for all sectors and regions in Sudan. The strategy for implementing such programmes constrained by lack of previous national and regional energy policies to serve as a guide. No exhaustive inventory and assessment of the potential new and renewable sources of energy has been carried out, especially in the area of woodfuel, the nation's major source of energy. Also there is a lack of manpower planning and training programmes. The energy assessment project, started in 1981, is providing good information. However the data are still being analysed. As an extension to this project, Sudan will start an energy management and planning project in June 1983 to develop an over all strategy for developing new and renewable sources of energy and to develop efficient and conservative ways to use energy. It is hoped that this project will assist

Sudan in its plan of action for establishing energy policies, defining priorities for development, and using all sources of energy in both short and long term actions.

To conclude, the remedial actions needed for expected energy shortages in Sudan are:

1. Afforestation

   A vast afforestation program needs to be undertaken in the Northern, Eastern, and Western Regions, and in Khartoum Province.

2. Efficient Use of Fuelwood

   Methods for more efficient production of charcoal and more conservative consumption of fuelwood (i.e., improved cooking stoves) need to be introduced.

3. Renewable Resources

   New technologies for using solar and wind power, agricultural residues, and geothermal power should be introduced, modified, and implemented. Renewable energy resources are most suitable for rural areas where the majority of Sudan's population lives.

To achieve these goals, the issues that cause constraints must be identified and resolved. These issues are:

1. Financing

   The lack of pre-investment studies, lack of energy surveys, and the complexity of the energy sector make it difficult to assess the financing needs. Development of hydropower and exploration for oil and gas require large sums of money which the country may not have. Volume and timing of external financing require cautions and precise planning.

2. Institutional, managerial, and technical issues

   The lack of trained technical personnel and good managers is a constraint to implementing the above mentioned goals. Personnel need to be trained to build up the Ministry's capabilities and reduce its dependency on expensive foreign consultants.

CHAPTER THREE

Dr. Sammani discusses the problem of water supply in rural Sudan. Describing the relationship between water resources, water sources, (the technologies applicable to local geologic structures), and the problem of environmental degradation, he notes that it is the areas with water that suffer from serious degradation problems. Dr. Sammani examines the distribution of water sources in six water deficient regions of Sudan and discusses the interactions that led to the degradation of the water source.

Institutional conflicts and fragmentation are largely responsible for many of the current problems. While there are several agencies that have a role in water planning, there is no agency in charge of monitoring and coordinating the entire system. The structural arrangement of the bureaucracy hinders the planners and technicians is every aspect of their operation. The chapter concludes with a list of actions that need be taken in order to remedy the problems of water supply in rural Sudan. These include recommendations at three levels:

1. The Macro Level -- to establish the legal and institutional infrastructure to better handle present and future ecological problems;

2. The Meso Level -- to build institutions that respond to ecosystem needs with consideration of user needs for the area; and

3. The Micro Level -- to formalize traditional systems (such as tenure) in order to develop adequate rehabilitation strategies as well as to create and monitor local projects so that they are more responsive to local needs and problems.

Pressure on Water Resources in Rural Areas

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INTRODUCTION

This paper concentrates on rural water supplies. It starts from the premise that pressure on water supply and water resources in rural areas is conjunctional with the distribution of water resources in relation to human activities in these areas: i.e., areas that have water sources are vulnerable to increased land use pressures and are consequently more open to environmental disturbances than areas with no or limited water sources.

Some clarification as to supply and resource has also to be made at the beginning to define the context of the paper in relation to the question of pressure. Water is supplied in rural areas from either natural or man-made sources. The former include perennial sources (rivers, swamps, lakes, etc.) and seasonal ones (streams, wadis/khors, and rain water collecting in different forms). The latter are comprised of bore-holes, hafirs and open-shaft wells, to which can be added rain water stored in Tebeldi trees (Adansonia digitata) which stands as an important source of supply in Hamar area in Western Sudan. Resources, on the other hand, consist of rain water, surface flows and ground water.

Both supply centres and the resources on which these centres are founded are open to pressures. Users reach the former to obtain their needs which are extracted through one means or the other from the latter. In assessing the pressure magnitude, it is easier to attack the question in relation to supply where communities in rural areas come in direct contact with the source. Assessing the impact of users on resources would require information and measurements beyond the scope of this paper. Therefore, our emphasis shall address pressure on supply sources in rural areas and, whenever possible, considerations related to the resource.

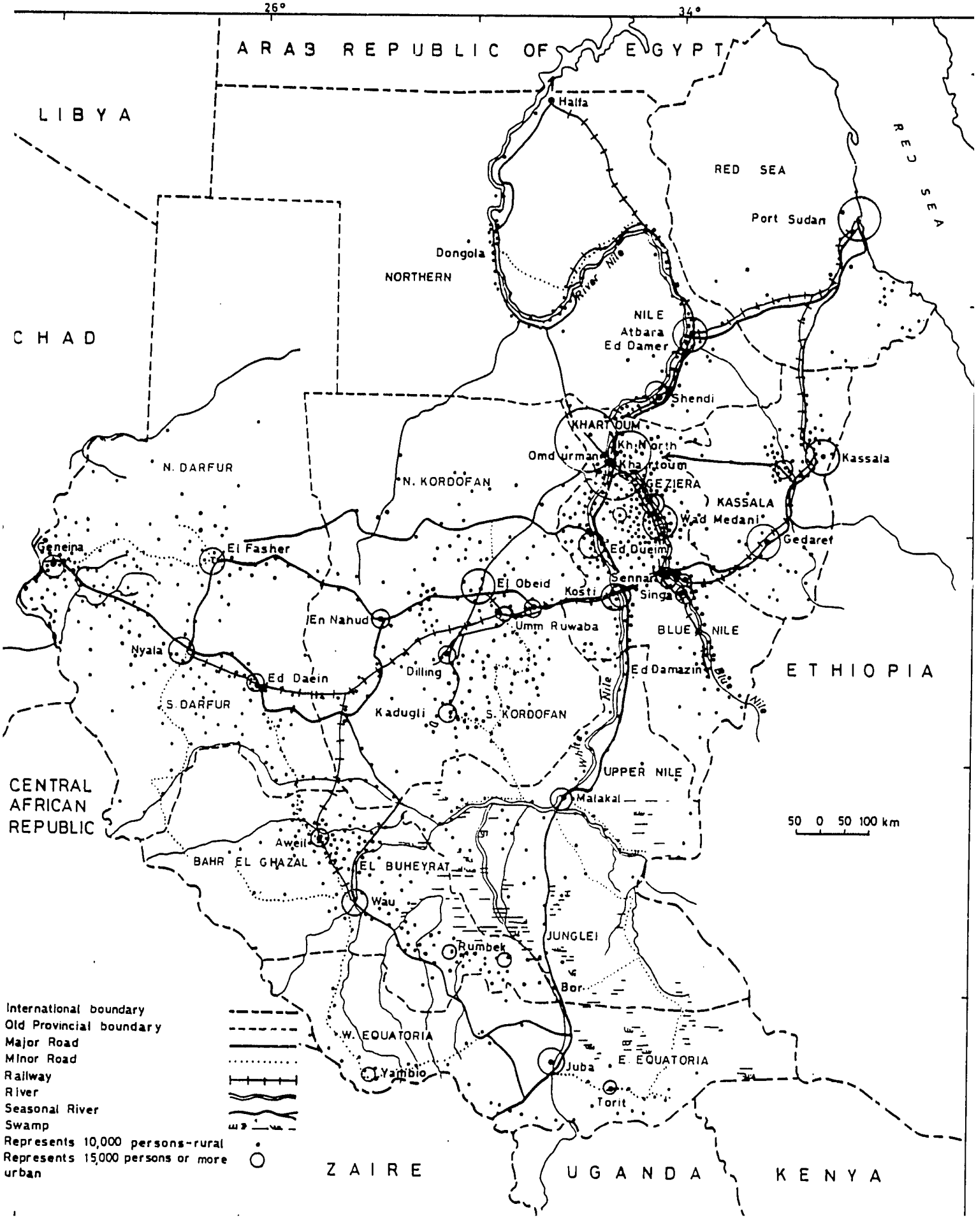
This chapter will examine the question of pressure in regional contexts, the present situation of water sources regarding availability, type and geographical distribution by region. It is equally important to present a picture of the conditions of use around these sources for the different regions. This shall be undertaken using the series of maps (Figures 3.1 to 3.8) for the six northern regions which relate water sources to population distribution (Figure 3.1). The six maps show the existing sources and a set of envelopes 5 km.,10 km., 20 km., etc., from source) served by these sources.

The maps were prepared by the writer in 1972 based on all existing bore-hole and hafir water sources at the time. Though some sources have been added since then, the general picture remains the same. During the last 10 years water provision on programmes followed the established pattern of the later 1960's and would generate little effect on the distribution picture presented by the six maps since:

1. Emphasis during the last 10 years continued to be on the drilling of bore-holes in geologically favourable areas therefore adding more water-points in areas that are already under heavy human and animal use;

FIGURE 3.1

POPULATION DISTRIBUTION



2. Only a few number of hafirs are being excavated; consequently the situation in areas served by hafirs is basically the same since 1972;

3. No water has been provided in the uninhabited or sparsely populated areas again, with the situation of 1972 maintained in these areas.

THE MAGNITUDE AND DISTRIBUTION OF THE NATIONAL PROBLEM

THE LOCATION/DISTRIBUTION BY REGION.

The Northern Region (Fig. 3.2). According to the 1973 census, the region has a population of 917,723 persons of which 170,085 are urban settled, 654,473 are rural settled and 92,165 are rural nomadic. The region is comprised of two provinces: The Northern Province and Nile Province.

This is one of the oldest settled regions of the country, judged from the remnant of ancient civilizations. The Nile remained the main source of water for agricultural purposes and other uses. Except for its southern parts (the area of Shendi Rural Council and the few wadis away from the river), human habitation is confined to the Nile strip and most communities are served by river within a radius of 5 kilometers. Other than the Nile, the main water sources prevalent are bore-holes and open-shaft wells. The river supplies settlements through:

1. filter-stations, mainly for the big towns and some of the intermediate rural centres;

2. the canal system of the many pump schemes found along the Nile strip throughout the length of the region;

3. water taken directly from the river.

Open-shaft wells are widely spread in the region. They used to be a main source of supply for the population due to nearness of the water table and the reliability of discharge. Two types of wells can be distinguished: communal wells on which whole settlements depend with several of them in one village, and the individually owned wells found in houses. Water from these wells is generally hygienic. However, physical exertion is needed to obtain the water. This last factor made their role decline in time, especially when an alternative source is found.

The number of bore-holes shown by Figure 3.2 has to be raised slightly to give the actual picture of distribution for this region. However, despite the fact that a sizeable part of the Northern Region is geologically favourable for bore-hole development, no extensive drilling of bore-holes is being undertaken in this region since the Nile is providing a reliable source.

With most of the population concentrated on the Nile banks and with the river as a perennial source of supply, the region was of low priority in the national programmes of water provision. The bore-holes that exist are mainly

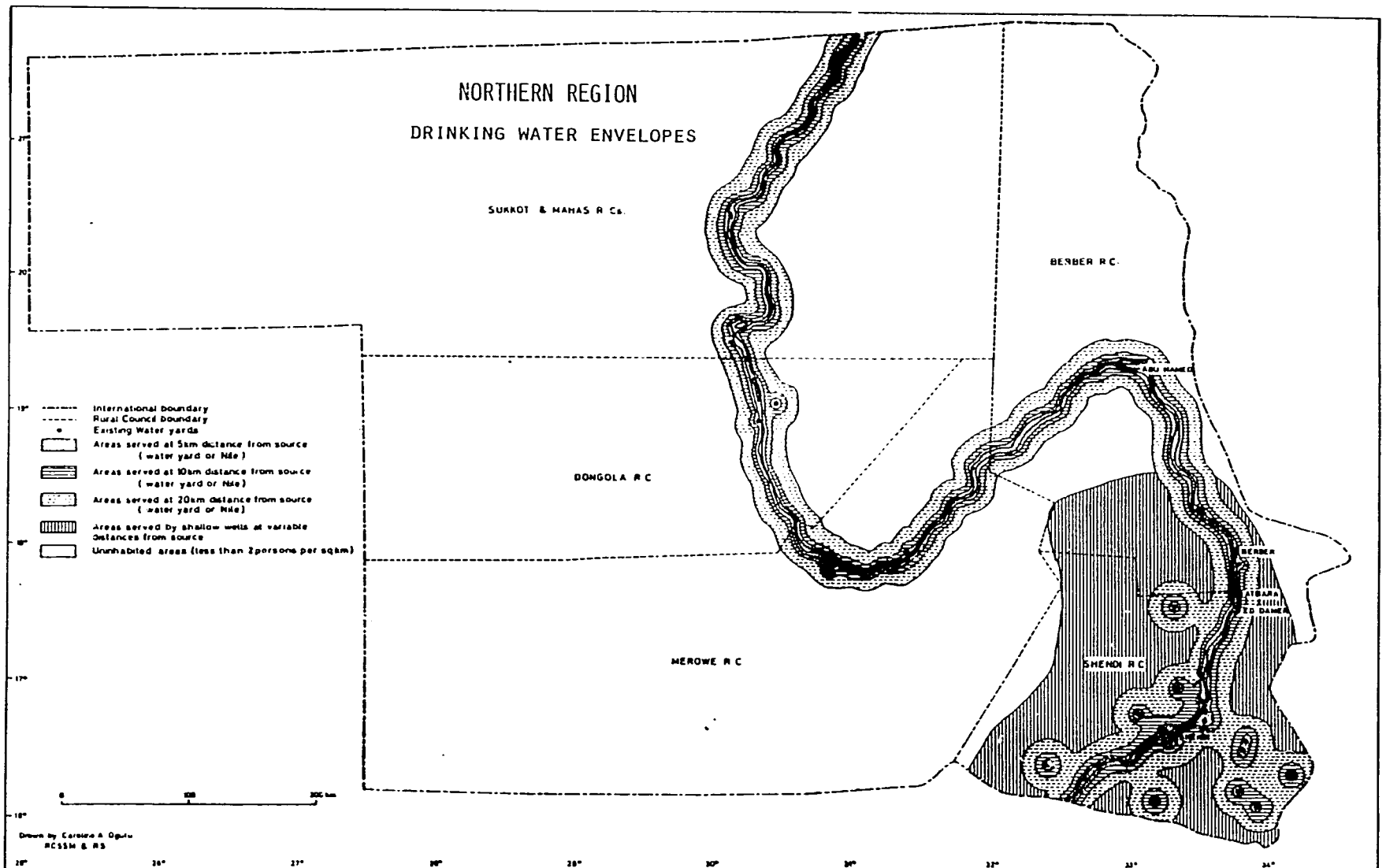

NORTHERN REGION
DRINKING WATER ENVELOPES
SUKKOT & MAHAS R Cs.
BERBER R C.
DONGOLA R C
MEROWE R C
SHENDI R C
BERBER
ATBARA
International boundary
Rural Council boundary
Existing Water yards
Areas served at 5km distance from source (water yard or Nile)
Areas served at 10km distance from source (water yard or Nile)
Areas served at 20km distance from source (water yard or Nile)
Areas served by shallow wells at variable distances from source
Uninhabited areas (less than 2persons per sqkm)
Drawn by Caroline A. Ogutu
RCSSM & RS

FIGURE 3.2

for the supply of big towns and those settlements at a distance from the river. The majority of these are to be found in Shendi Rural Council. The presence of pastoral communities utilizing the southern parts of this area with its semi-desert scrub vegetation has necessitated the provision of this source.

The Eastern Region (Fig. 3.3). This region has a population of 1,497,381 persons of which 388,851 are urban settled, 693,174 are rural settled, and 415,256 are rural nomadic. The region is made of Kassala Province and the Red Sea Province. From Fig. 3.3 it is evident that four types of sources are available in this region. These are bore-holes, hafirs, open-shaft wells, and perennial sources.

Bore-holes are concentrated in the two rural council units of Northern and Southern Gadaref where it has been possible to reach the ground acquifers of the Nubian sandstone overlain by basaltic formation. Outside this area the dominance of the basement complex formation made it impossible to undertake drilling programmes. Other inhabited areas have to rely on sources including hafirs, open-shaft wells plus the available rivers.

Hafirs constitute an important source of supply in this region. The extensive black cracking clay soils together with the high amounts of rainfall received in the southern parts of the region made it possible to develop hafirs to meet the water requirements of these clay plains. Hafir excavation programmes were started in this area in the mid 1940's coinciding with the introduction of "harig" cultivation and later the expansion in mechanized farming. These programmes have slacked from the early 1970's due to increased attention given to drilling activity.

Open-shaft wells are widely spread in the region due to the presence of seasonal streams. The Gash and Baraka flush large areas and replenish the shallow acquifers on which these wells are founded. Besides the two streams, the area is transected by numerous wadis, especially in the Red Sea Hills region. Many well fields are developed on the beds and flood plains of the wadis. Area-wise, it can be remarked that a large part of Kassala region depends on open-shaft wells. They act as centres of dry season concentration for the greater part of the nomadic groups inhabiting the region.

The perennial sources are represented by the Atbara river, the Siteit river, and the canal system of the New Halfa Scheme which takes water from the Atbara river. The Atbara is the source of supply for the populations living on its banks as well as for many of the nomadic groups of Eastern Sudan and some of the nomads coming from the Northern Region. It also acts as a corridor facilitating the movement of the two groups of nomads between New Halfa area and the Nile lands of the Northern region in search or grazing and seasonal employment in agriculture.

The canal system of the New Halfa scheme supplies water to the population as well as to migrant groups who visit the scheme area during the dry season. Water is either obtained directly from the canal or from filter stations. The scheme, developed in the early 1960's to accommodate the Nubian population affected by the construction of the High Dam, had to provide services including

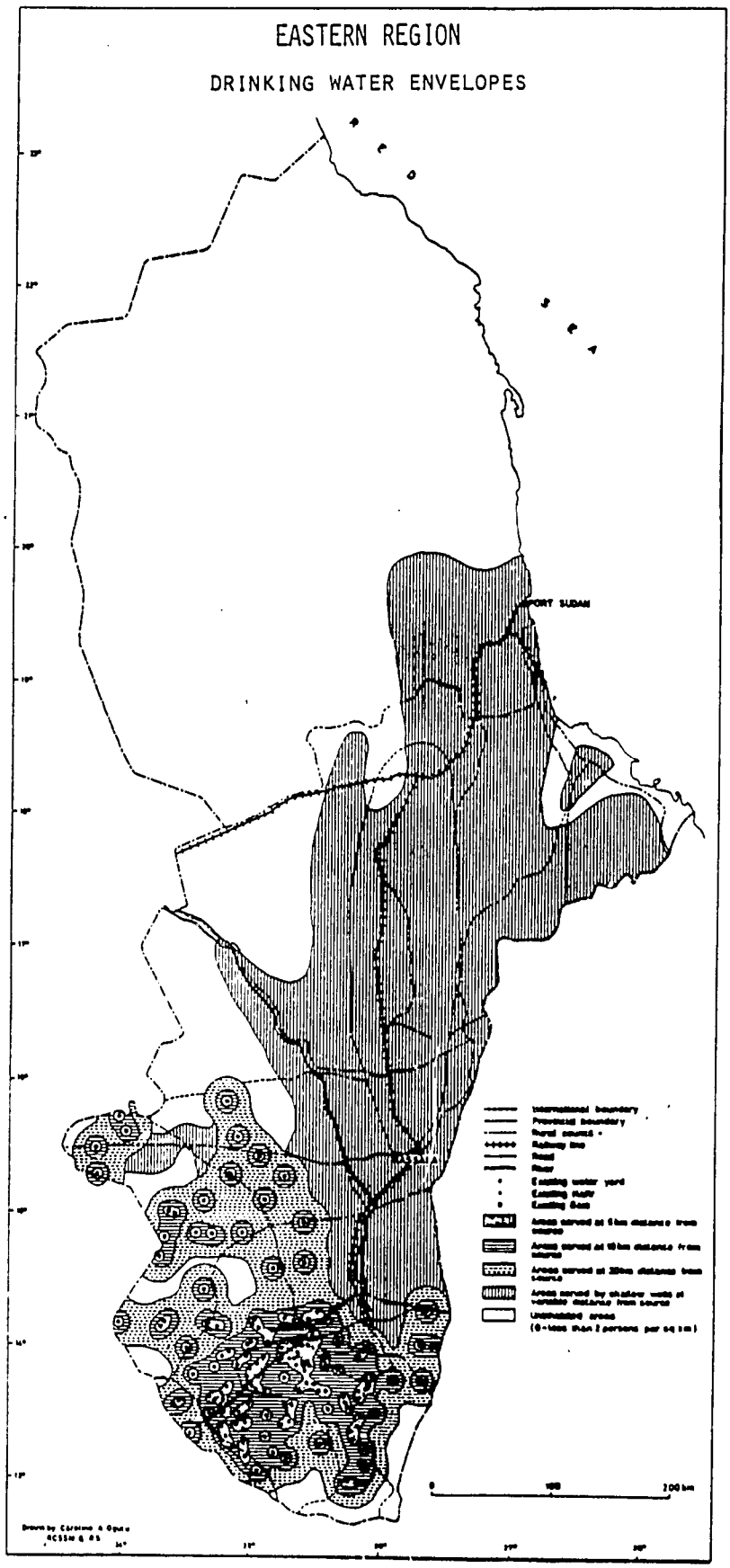

EASTERN REGION
DRINKING WATER ENVELOPES
PORT SUDAN
KASSALA
0
100
200 km

FIGURE 3.3

water supply for the resettled population as well as for the local nomadic groups which were incorporated in the later stages of its development. In total there are 43 filter stations in the scheme area of which 25 are to be found serving the 25 planned Nubian settlements having a total population of 51,000 persons. The remaining 18 filters are serving 18 settlements out of 52 occupied by people of nomadic origin which have a total population of 140,000 persons. This shows a wide discrepancy between the two areas and, as a result of the shortage in the number of filters, most of this latter category of settlements obtain their supply directly from canals.

Khartoum Province (Figure 3.4). The province has a total population of 1,095,617 persons with a settled urban population of 784,294 persons, a settled rural population of 256,327 persons, and a rural nomadic population of 54,996 persons. Away from the urban agglomeration of the three towns, the rural areas of the province are served by three sources: the perennial ones (comprised on the White Nile, the Blue Nile and the Nile), bore-holes, and open-shaft wells.

The supply from the rivers is either obtained directly, through filter stations, or from the canal systems of agricultural schemes where the latter exist. Filter stations are limited in number. The river as a direct source is accessible only to those settlements close to it. However, for livestock needs the rivers remain the main source for large populations. Bore-holes are provided to meet the supply needs of those settlements that lie at a distance from the river. In most cases these are old established villages ranging in population size from 1,000 to 3,000 persons. Formerly, they used to obtain their supply from either the river or from open-shaft wells. Open-shaft wells are found in many of the settlements of rural Khartoum Province where they used to be a main source of supply. Their importance has diminished and presently they are confined to those grazing areas away from the rivers.

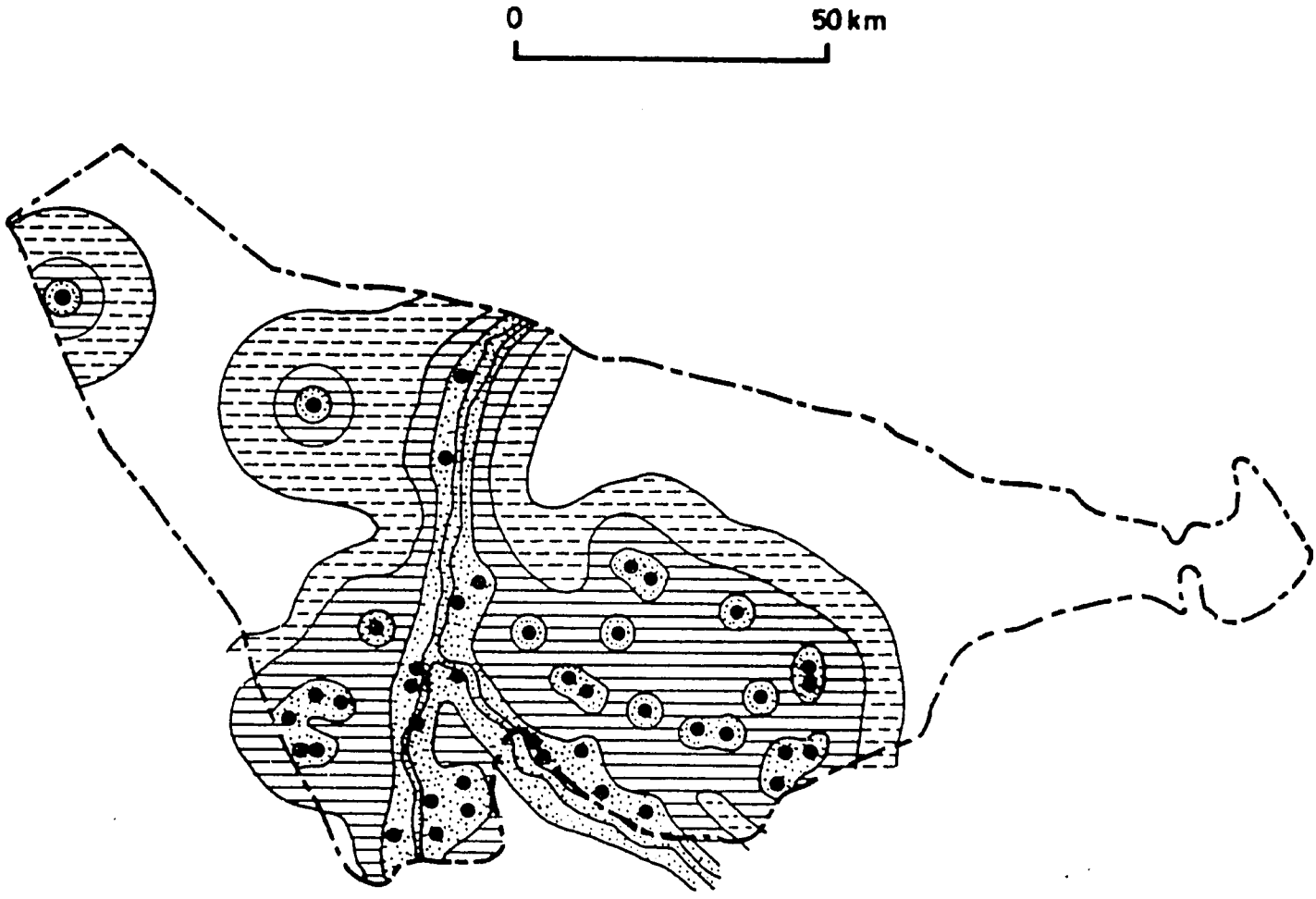
The Central Region (Figure 3.5). The region has a population of 3,623,238 persons. Out of this figure 517,038 persons are urban settled, 2,184,269 are rural settled, and 673,492 are rural nomadic. It is comprised of three provinces: The Gezira, the White Nile, and the Blue Nile.

As in the case of the Eastern Region, the variation in the physical environment together with the impact of development activities -- planned and unplanned -- has resulted in a wide diversity in land use, human habitation, and modes of living. The economics of the region range from irrigated agriculture in state owned schemes such as the Gezira, Rahad, Suki, etc., to mechanized farming being extensively practised in the southern half, to traditional subsistence agriculture pursued mostly in the southern parts of the region, to pastoral nomadism which prevails along the White Nile and the southern parts of Blue Nile.

The physical factors plus the development impact have had their influence on the distribution of water sources. The main forms are the perennial sources, bore-holes, hafirs, and open-shaft wells.

Two perennial sources, the White Nile and the Blue Nile, run along the eastern and western fringelands of the region. On them depends the settled population inhabiting their banks plus the livestock of both the settled

KHARTOUM PROVINCE
Drinking Water Envelopes



Provincial boundary

Existing water yard

Areas served at 5km distance from source (water yard or the river)

Areas served at 10km distance from source (water yard or the river)

Areas served at 20km distance from source (water yard or the river)

Areas served by shallow wells at variable distances

Drawn by Caroline A. Ogutu
RCSSM & RS

FIGURE 3.4

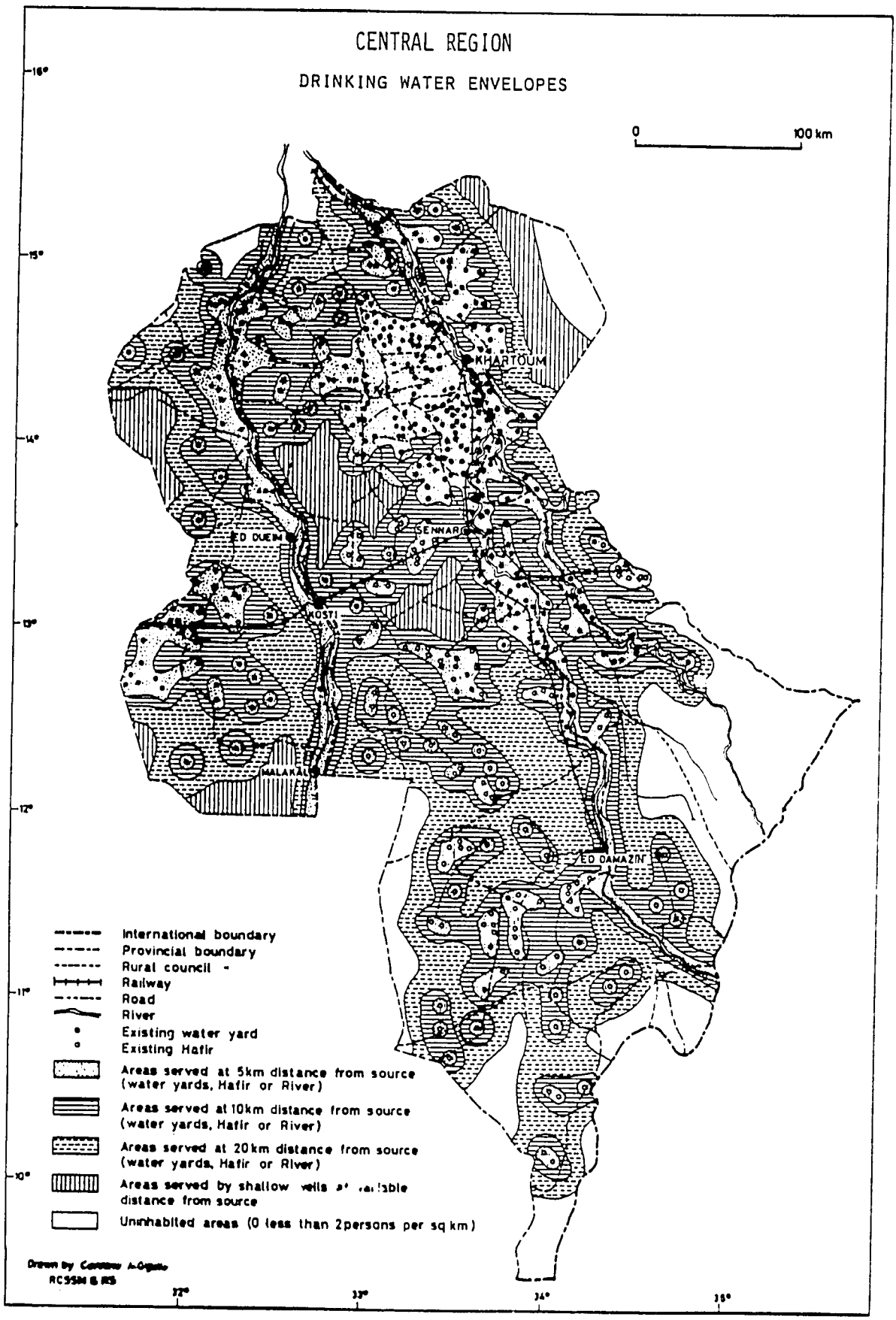

CENTRAL REGION
DRINKING WATER ENVELOPES
0
100 km
KHARTOUM
SENNAR
ED DUEIM
KOSTI
MALAKAL
ED DAMAZIN
16°
15°
14°
13°
12°
11°
10°
32°
33°
34°
35°
International boundary
Provincial boundary
Rural council
Railway
Road
River
Existing water yard
Existing Hafir
Areas served at 5km distance from source (water yards, Hafir or River)
Areas served at 10km distance from source (water yards, Hafir or River)
Areas served at 20km distance from source (water yards, Hafir or River)
Areas served by shallow wells at variable distance from source
Uninhabited areas (0 less than 2persons per sq km)

FIGURE 3.5

communities and the nomads utilizing these lands with large populations taking their supply directly from the two sources. The two rivers are important as feeding sources to the irrigation schemes found in the region where water is taken directly from canals or from the filter stations connected to them.

Bore-holes stand as the second important source of supply in this region judged from their geographical spread and number. Figure 3.5 shows a concentration of this source in the Gezira Scheme area. This has come with the rise of the Social Services Department in the early 1950's since the provision of clean hygienic water supply to tenants' settlement emerged as one of the basic social development targets served by the department. Accordingly the majority of settlements are being supplied by bore-holes. Two factors contributed to the success of this programme: (i) the location of a good part of the Gezira Scheme area within the geologically favourable Umm Ruwaba series formation, and (ii) the steady funding made available through the years to the Social Services Department from the proceeds of cotton (2 percent of the income generated from the crop) to be spent on its programmes including water supply. The maintenance of water sources is done by the Local Government Councils to which different parts of the scheme belong.

Hafirs stand as a dominant source of water in the southern parts of the region. Programmes for hafir excavation were initiated in the 1940's on the same philosophy that guided this activity in the Eastern Region, i.e., to open the vast but sparsely populated clay plains. The scarcity of water had put much of this land out of the reach of the local population. Three population types were targeted to be served by hafirs:

i. The settled communities pursuing traditional economies, being the ones inhabiting the hilly areas such as the Ingessana group, or those scattered in the plains;
ii. The nomads utilizing the clay plains and carrying seasonal migrations between the southern reaches of the region for dry season grazing and its central parts for rainy season grazing; and,
iii. The mechanized farming communities, which again as in the case of the Eastern Region started with "harig" cultivation which developed with time into large areas of planned and unplanned mechanized schemes.

In this context, hafir programmes have succeeded in opening the southern parts of the region to human use as well as linking distant areas that were disconnected in the past.

The hard clay surface predomination in most of the region has not aided the development of open-shaft wells to a large extent. However, they assume an important role in some localities where the geomorphological conditions favour the digging of wells such as in some parts of the Butana plain, the extensive sandy areas on both sides of the White Nile, and the water-sheds and beds of wadis bisecting the southern parts of the region.

Kordofan Region (Figure 3.6). The Kordofan Region has a population of 1,032,253 persons. The urban settled population amounts to 132,978 persons while the rural settled comes to 687,849 persons with a rural nomadic

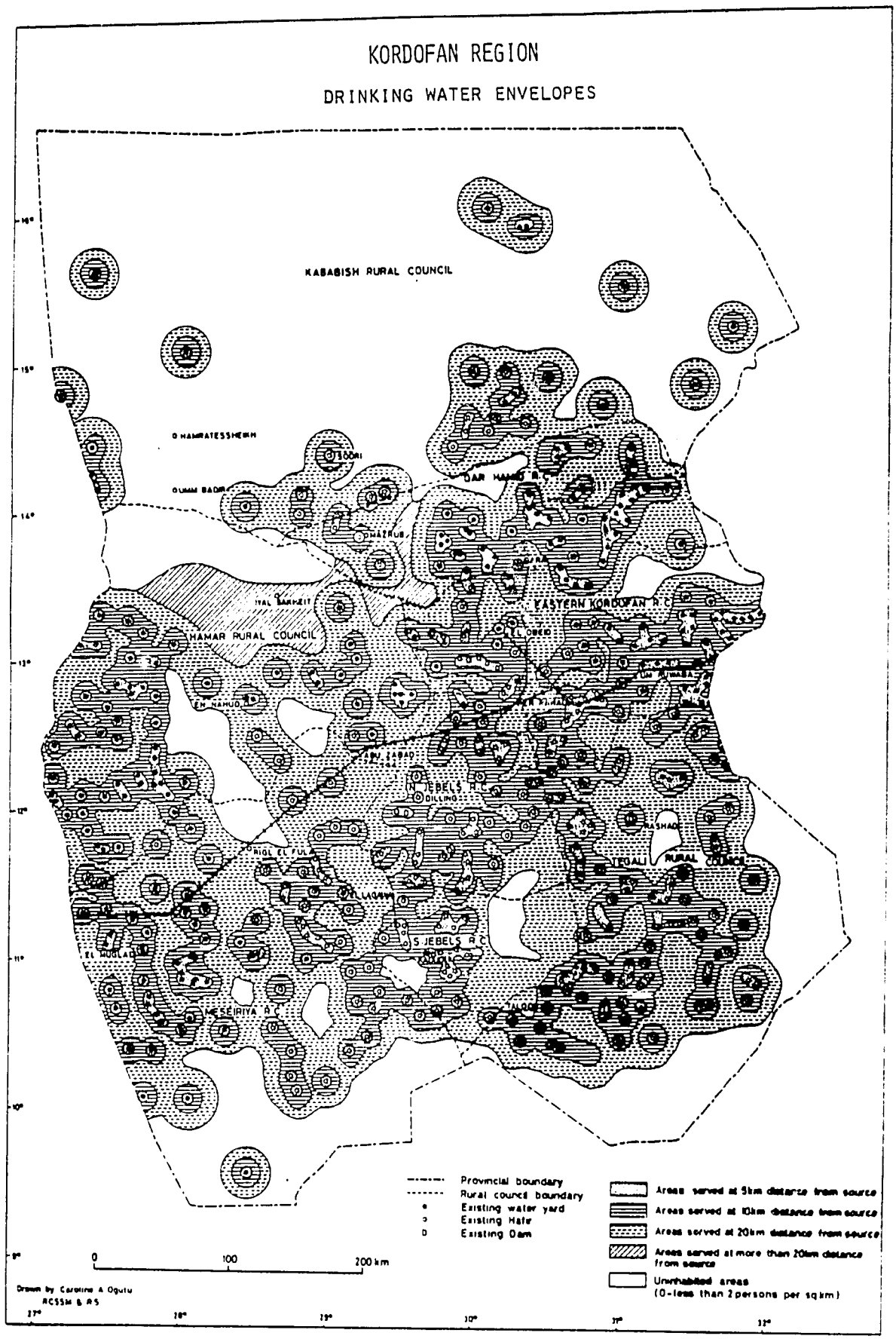

KORDOFAN REGION
DRINKING WATER ENVELOPES
KABABISH RURAL COUNCIL
HAMAR RURAL COUNCIL
EASTERN KORDOFAN R.C
N JEBELS R.C
S JEBELS R.C
KESEIRIYA R.C
TEGALI RURAL COUNCIL
Provincial boundary
Rural council boundary
Existing water yard
Existing Hafir
Existing Dam
Areas served at 5km distance from source
Areas served at 10km distance from source
Areas served at 20km distance from source
Areas served at more than 20km distance from source
Uninhabited areas
(0-less than 2 persons per sq km)
0
100
200 km
Drawn by Caroline A Ogutu
RCSSM & RS

FIGURE 3.6

population of 211,426 persons. The region includes the two provinces of Northern Kordofan, and Southern Kordofan.

Due to the north-south extension of the region, it experiences three climatic types with three vegetation zones: the semi-desert, dominant in the north; the savannah low rainfall in the central third; and the savannah high rainfall in the south. This variation in climate, especially rainfall, coupled with differences in soils (the northern half exclusively sandy, while the southern area predominantly clay) has caused wide distinctions between its northern and southern parts in terms of land use and type of economy.

Traditional rain-fed farming prevails in both the northern and southern parts. However, there is wide variation in types of crops grown, practises applied, and of the size of the areas cultivated. While mechanized farming is developed in the southern parts, it is non-existent in the northern ones. The cattle nomads, the Baggara group, predominate in the southern areas, compared to the camel nomads, the Abbals group, who predominate in northern areas. The populations practising these economies depend for their water supply on five types of sources: bore-holes, hafirs, open-shaft wells, rain-water stored in Tebeldi trees, and perennial sources in the southern parts of the region (utilized by the Baggara nomads during dry season).

Bore-holes are an important source of supply. The majority of bore-holes exist in the north central part of the region with an intrusion to the south west (Figure 3.6). This pattern is closely associated with the location of the Umm Ruwaba series and the Nubian Sandstone geological formations, on which this source is founded. Prior to the development of bore-holes the areas obtained their supplies from seasonal water sources (khors and wadis, plus ponds fed directly by the annual rainfall) and very localized open-shaft wells. With the progression of the dry months, villagers and nomads used to concentrate until the onset of the rains at the available centres of permanent supply. The drilling of bore-holes made it possible for the local populations to obtain supplies from sources that were beyond the reach of the traditional technologies. With time, reliability on bore-holes has become more established. This is partly due to the physical conditions of the area. Comprised of sand with flat or rolling dune formations, the area has limited potential for the development of hafirs while the sites suitable for open-shaft wells are very localized. The increases in human and livestock populations with the rise in settlement sizes have strengthened the dependency on bore-holes. However, despite the many sites drilled, their capacity in serving the population is limited. The greater part of the area depending on them is served at distances of 10 or more kilometers from source.

In comparison, hafirs are dominant in the southern half of the region. Here the clay soils together with the high intensity of rainfall and the availability of high lands (Nuba Mountains) and seasonal streams have aided in their development. Hafir excavation was started in this area in the mid 1940's on similar considerations to the ones discussed under the Eastern and Central regions. They were developed as a means to attract human habitation to the clay plain country, which was almost uninhabited at that time except for the seasonal crossing by the Baggara nomads. Some of the hafirs were developed

near Jebels to serve the already established hill communities while others were provided to facilitate the trekking of livestock from the production areas in Southern Darfur to the Kosti meat factory which was in operation in the early 1950's. Most of these hafirs were of small size, up to 15,000 cubic metres. They were deliberately designed with a limited capacity so as not to allow high animal concentration around them, especially toward the late dry season, as a measure to check overstocking and the resultant deterioration.

With the advent of mechanized farming and the vast expansion of this activity in the last decades, hafirs have emerged as important sources of water supply. Large capacity hafirs of up to 100,000 cubic metres and more have appeared for the farming communities associated with this development.

Open shaft wells are an important source of supply for many areas in the region. Most of Dar Kababish comprising the northern parts of Kordofan, and Dar Hamid area to the southeast of it, depend on open-shaft wells. The same is true for many localities in the Nuba Mountains region. In all these areas the presence of shallow acquifers or wadis and khors accounts for the development of this type of source.

Finally, there are those areas that depend to some degree on rain water stored in Tebeldi trees to be found in the north central parts of Hamar district. Here the geological and soil formation types constrain the development of any of the above known types of sources. Some time back in the early 19th century the local population discovered the technique of excavating Tebeldi and storing rain-water in its trunk. Initially this source was not adequate in meeting the population needs for the whole of the dry period. The source was augmented by the watermelon crop grown on wide areas to provide for some of the supply required for animals. Many of the villages practised migrations during the dry season to centres of abundant supply. With time, due to the increase in human and livestock populations which was unmatched by expansion in the supply from Tebeldis, with most of the latter collapsed. The population resorted to water transported to the villages by trucks. Due to the acute shortage of water faced by this area during the dry season, it is noted as a problem area.

Darfur Region (Fig.3.7). The Darfur region has a population of 2,076,733 persons of whom 188,642 persons are urban settled, 1,476,551 persons are rural settled, and 411,580 persons are rural nomadic. The region is made of the two provinces of Northern and Southern Darfur.

Darfur shows some similarities to the Kordofan region in terms of physical composition and prevalent land use and economic systems. Two main forms of livelihood predominate: traditional farming and some irrigated agriculture in the Jebel Marra area, plus livestock raising. Mechanized farming has just started in the southern parts of the region and has not yet assumed a leading role similar to that of the Southern Kordofan region. The distribution of the settled population is very much determined by the availability of water sources. The same factor conditions, to a large degree, the north-south migration of nomadic groups. The latter have a similar composition to that of Kordofan region. The Abbala group dominates in the northern part and the Baggara dominate the southern part practicing a pattern of migration that puts pressure on those lands lying in the centre of the region. The main sources of supply

in Darfur region are bore-holes, hafirs, open-shaft wells plus perennial sources in the Jebel Marra area and the southern borderlands of the region.

There is a marked concentration of bore-holes in the eastern part of the region and the southeastern portion with a few more in El Fasher District to the centre. As in other regions, the availability of bore-holes follows the water bearing acquifers. Dependency on this source involves travelling long distances as envelopes of more than 10 kilometers are common. This pattern is dominant in most of the areas served by bore-holes (Figure 3.7).

Hafirs are found in the southeastern parts of the southern Darfur Rural Council and in those areas bordering the Jebel Marra region from the northwest. The prevalence of clay soils and a good surface hydrology have aided the development of this source in the two areas.

Open-shaft wells constitute an important source that supplies many areas in Darfur region. Open-shaft well supply is dominant in the central and western parts of the region. The two areas lie in the surroundings of Jebel Marra, where the water courses running from the Jebel replenish the shallow acquifers on which this source depends.

The perennial sources include those found in the form of streams and lakes in the Jebel Marra region on which many settled communities are founded. There are also the Bahr El Arab and Bahr El Ghazal on the southern borderland of the region which are utilized by the Baggara nomads during the dry season.

THE MAGNITUDE OF THE NATIONAL PROBLEM

Based on the previous discussions on the water supply situation by regions, the following conclusions can be derived for the northern part of the country:

1. Despite the efforts made in this field that yielded successive programmes of water provision, most of rural Sudan is not yet adequately served by water sources, judged from the areas served by the three envelopes (5 km., 10 km., and 20 km. from source). Even if the 5 kilometers radius is accepted as a convenient walking distance to water, the greater part of the country does not qualify for this criterion.

2. Natural sources of supply are still essential in meeting the needs of many populations. Here, questions related to hardships in obtaining water arising from seasonality of supply, long walking distances to source, or migrations of whole populations in the case of nomads are well exemplified. Moreover, the quality of water obtained is unhygienic in many cases.

3. There is an obvious inequality in the distribution of water sources in relation to population needs evident at all geographical scales from the local level to area and regional levels. Much of this inequality can be attributed to the kind of water technology and water planning

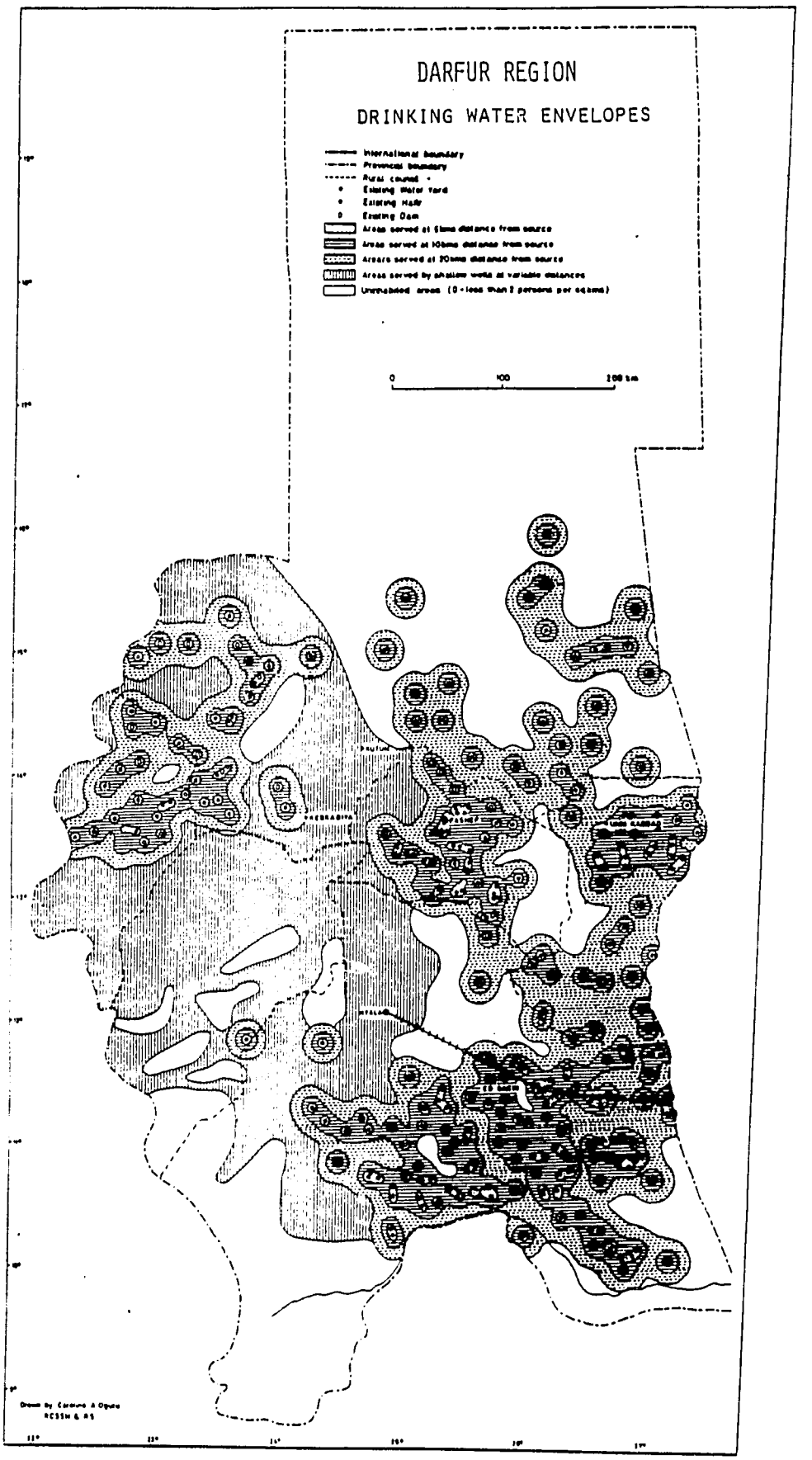


FIGURE 3.7

applied in the country. So far, four types of technologies for supplying water to rural areas are in use: bore-holes, hafirs and dams, open-shaft wells and filter stations. Since the practicability of each for a situation is conditioned by certain physical requirements, many areas in the country are left unserved because such requirements cannot be universally met. With bore-holes being concentrated in the geologically favourable areas, filter stations conditioned by the proximity to perennial sources, hafirs determined by the surface hydrology, and open-shaft wells by the location of shallow acquifers, there emerged an eminent imbalance between water sources location and population distribution and needs.

4. Even within the four known technological devices, there are imbalances in the programmes executed which can be explained in terms of the perception of the planner to different types of sources. In the 1940's and 1950's hafirs held very high priority and massive programmes of this sources were executed. This interest shifted in the sixties to bore-holes. The professional dominance of certain specialization, i.e., surface water engineers in the earlier period and geologists and drilling engineers in the later one, coupled with the community outlook towards the type of source is very much behind this differentation.

5. Because water provision is taken as an end in itself and not viewed in the context of other impacts, alternative approaches are neglected in the planning of water programmes. It continued to be the established practice to supply water where populations are found to exist. The alternative of moving people to sources of supply using the same funds allocated for the new sources has not been attempted although it may prove specially feasible at the micro level where the social costs are minimal.

6. Many of the water sources, including hafirs, open-shaft wells plus many of the natural sources, are of seasonal nature, i.e., they support populations for only part of the year. The phenomenon is also true for bore-holes when they break down. This seasonality magnifies further the imbalances between the available sources at one time and the actual requirements and is highly reflected in the seasonal migrations for water.

Analysis leads to a basic fact that the existing water sources are not adequately meeting population needs with the result that needy populations have to search for water. This is the main force creating pressure on the available water sources. The shortage in supply is demonstrated by the following statistics:

> In 1975 the total water requirements for human and animal populations based on calculations made by the Rural Water and Development Corporation amounted to 334 million cubic metres. Of this amount about 86 million cubic metres were required for human supply, and the remaining 248 million cubic metres for animal needs. [This is expanded on in Table 3.1].

TABLE 3.1

ANNUAL WATER REQUIREMENTS BY USER CATEGORY

Type	Daily Requirements in Gallons Per Head	Annual Requirements in Cubic Metres Per Head	Total Population in Millions	Total Annual Water Requirements in Million Cubic Metres
1. Humans	4	7.2	12	86.0
2. Camels	2	3.6	3.6	13.0
3. Cattle	6	10.8	13.3	144.0
4. Donkeys, Horses, and Mules	4	7.2	2.5	18.0
5. Sheep	2	3.6	12.2	44.0
6. Goats	2	3.6	8.0	29.0
TOTAL				334.0[2]

SOURCE: El Sammani, M.O., The Magnitude of the Drinking Water Problem in the Sudan. Economic and Social Research Council, 1976, p. 18.

> The supply available from bore-holes is in the region of 16 million cubic metres per annum, given by about 1,000 bore-holes, each producing 16,000 cubic metres. That from hafirs and small dams also comes to about 16 million cubic metres. Open-shaft wells contribute about 2 million cubic metres. An estimated additional supply of 30 million cubic metres comes from natural sources thus bringing the total amount presently available to 64 million cubic metres. The amount of water required to meet the present shortage is in the region of 270 million cubic metres (El Sammani M.O. 1978, 98).

This large deficit is partially met by dependency on natural sources. The whole of Southern Sudan, for example, depends on this type of source. Most of the Baggara nomads carrying migrations to the riverian lands of the White Nile, Bahr El Ghazal, and Bahr El Arab depend on these sources for the whole of the dry season. The same applies for those nomadic groups spending the dry season on the banks of Blue Nile, White Nile, the Nile proper and River Atbara. Besides, in fact, part of this deficit is never met since the consumption rates for different users (human and livestock categories) specified in Table 3.1 are never met. Thus, a situation exists of either a complete lack of supply or a seasonal one. For most communities, the shortage between what is required and what is available is relieved by depending on sources outside the community. This explains the presence of the envelopes in Figures 3.2 to 3.7.

CAUSES AND CORRECTIVE MEASURES

The causes of the pressure experienced by water sources are multifold. They relate to planning and management issues. Equally, there is the impact of the rising need for water due to the increase in number of users and the expansion in domestic requirements of the rural population. Furthermore, the situation has been aggravated especially in recent years by insufficient maintenance. The expertise needed and the expense of proper maintenance schedules is far beyond the capabilities of the local councils and the local communities. This has resulted in the dysfunctioning of many bore-hole and hafir sources putting an extra load on the functioning ones. Finally, there is the effect of invasion of whole ecological zones by outsiders. Most pronounced in the savannah belt, the degradation of the northern semi-arid areas has sent human and livestock populations southwards at phenomenal rates. In what follows the causes shall be elaborated.

Inadequacies of Planning

As noted earlier, water is provided where one of the common devices in use can be applied. This is a basic shortcoming since balanced distribution in relation to actual requirements cannot be achieved. This is especially true in most of the areas outside the irrigated schemes. The imbalances create pressure on the existing sources. Local pressure develops into area pressure arising from the mobility of settled population and their livestock in search for water, especially during dry season. At a higher scale, the area pressure generates regional pressures associated with nomadic migrations, again during dry season.

The migrating village population referred to as Dammara live under miserable conditions in those dry season camping areas which have a water supply. ....They suffer from shortages in staple food crops, mainly dura, as what they carry with them from their original village does not last them through the dry season, and they have to purchase additional quantities from merchants, often at higher prices. Their housing is very poor as they put up temporary shacks from what-ever material available to them....

The drawbacks of dry season migrations are not limited to the problems encountered at the watering centres. They also affect the life of the migrants when they return to their villages. As they cannot return before the start of the rains which secure them a safe drinking supply, their movement back often starts very late, resulting in inadequate preparation for the new cultivation season. Not preparing the fields in the proper way, or missing a rain or two during the sowing period greatly adds to the risks of crop failure in such marginal regions. Similarly, shortages in drinking water during the harvest may force an early migration to the watering centres and prevent them from harvesting a substantial part of their produce. The same is true for gum production as the lack of drinking water during the dry months keeps many of the potentially producing areas out of the reach of the producers. Early desertion of their villages and late journeys back leave the farmers without adequate time to repair their houses.

Another effect of migration is the pressure put on those services available at the water points which were originally provided to meet the requirements of the local population without consideration of migrants from other areas. In the case of medical facilities (dispensaries and dressing stations), a shortage of drugs is evident during the dry months. Also police and court services have to handle more cases during this period. This poses a planning problem because the movement of the migrant population varies in size from year to year, depending on conditions of rainfall, so it is difficult to estimate the actual needs of the Dammara (El Sammani 1977, 277-278).

Besides these forced inadequacies due to limitations in means of supplying water, there are inherent gaps in the planning and provision of water sources. The planning process passes through the following stages:

1. Receipt of proposals of new sites to be supplied with water;

2. Location of sites by area on maps, and examination of their water situation in relation to existing sources;

3. Field surveys of proposed sites and stocktaking of physical and socio-economic data to assess viability of the site for inclusion in the programme;

4. Analysis of information for sites studied by area to set priorities;

5. Priorities ranked for whole region with the regional programme concluded;

6. Regional programmes assimilated at national level to arrive at national programme; and

7. Programme implemented.

Many gaps can be pointed out too, in this planning technique:

1. Only those sites that are liable to be served by one of the known means (bore-holes, hafirs, open-shaft wells, perennial sources) stand a high chance of being selected for consideration in the area studies. The result is that many sites are excluded from the start, which leads to aggravating the conditions in areas already experiencing pressure. Though in the case of the latter a new water source might be added if the area is geologically favourable thus relieving a pressurized site, the new development occurs within an already affected area and addresses only a matter of scale. The apparent lack of extensive geophysical investigation in areas that are customarily held as geologically unfavourable coupled with the absence of research in the field of surface hydrology and engineering design in both the clayey and sandy areas, combined with the low priority accorded to innovative solutions such as piped water from rich sources, water transported by trucks, or attempting harnessing rain-water and have all contributed to limiting the alternative available to those parts of the country already suffering from thirst. Table 3.2 illustrates this shortcoming. The figures are given for the 1969/70 programme. The same picture can be taken as valid for the 1981/82 programme.

2. Whether a new programme site is selected on domestic use or on land use considerations (social improvements) or on land use considerations to increase area under cultivation or open land for grazing (economic improvement) the outcome leads to adverse effects in the long run due to a number of misconceptions. The basic assumption on which the planning philosophy is founded is that water acts as a mobilizer of a whole set of changes in an area. Once water is made available it leads to the stabilization of the community utilizing it. It increases agricultural production, improves local economies, and attracts social services to the developed site. This has its roots in the old philosophies on which the Soil Conservation Board and Committee were founded. True, water might lead to all the results listed above, however, at the same time it shall generate a whole chain of negative changes. Therefore, as there is a basic assumption conditioning the planning process, there is a basic omission that generates false attributes of the merits of this process. It arises from the basic misconception of water in the context of other variables. Since water sources are not provided in the frame of land use plans that integrate the site developed into the resource potentials and use at the

the scale of the area and region, a newly developed site adds to the already existing confusion. This is because the site shall be freely accessible to any user, being from within the locality or an outsider coming with his livestock from a nearby or distant land.

> The supply of drinking water should take into consideration not only the demand of the central place itself, but also that of surrounding settlements and the herds which pass through the area on their seasonal grazing movements. ...The increase of drinking water supply should, however, go hand-in-hand with the development of the whole area so as to avoid an ecological imbalance based on abundance of drinking water while grazing and other resources are lacking. (Mensching, H., and Ibrahim, F. 1980, 9).

There is an apparent gap of quantification in the planning exercise so far applied which needs to be corrected if sound planning is to emerge in the future.

3. The confusion that has accompanied water provision is further exacerbated by another gap, namely the absence of monitoring systems after water is provided. This is accounted for in essence by the previously discussed omission: incomplete objectives and the sectoral approach followed by the agencies concerned in one way or the other with the water provision programmes. These agencies work in an unintegrated fashion. The Land Use, Soil Conservation and Water Programming Administration is the unit responsible for the preparation of the annual programme of water provision at the regional and national level. It is comparatively well staffed with the essential professions (in the physical and social fields) to undertake this task. However, its role stops at the stage of programme preparation although according to its terms of reference it has to follow that by undertaking all the conservation measures that assure sustained yields from ecosystems. So far, little has been done in this area due to the lack of understanding of this role by policy makers. Not being viewed as urgent in nature; it therefore receives low priority. This is reflected in the small budgets allocated for projects geared to the monitoring of ecosystems. The National Corporation for Water on the other hand operates from the premises that its role finishes with the erection and operation of the water source at the developed site.

The other units concerned include: The Range Management and Pasture Administration; The Forestry Administration, and The General Administration for Animal Resources. For all these units water is a service to meet their special requirements of resource utilization. Though a General Administration for Natural Resources has been created in 1976 incorporating three of the above units (Soil Conservation, Range and Pasture, and Forestry) in realization of the need for integrated natural resource planning, little has been done in this area and the gap remains to be closed.

TABLE 3.2

SITES STUDIED FOR 1969/70 PROGRAMME

Compiled from the files of the Rural Development Department (Programming Section).

Province and Rural Council	Number of Sites Studied	Recommended for Boreholes	% of Total Studies	Recommended Shallow Wells	% of Total Studied	Recommended Hafirs	% of Total Studied	Recommendation not Specific	% of Total Studied	Not Recommended	% of Total Studied
KORDOFAN PROVINCE											
Eastern Kordofan	284	135	47	52	18	1	3	20	7	76	26
El Messeriva	121	56	46	11	9	6	4	10	8	38	31
El Bederiva	7	2	28	–	–	–	–	3	42	2	28
El Kababesh	41	18	43	12	29	1	2	–	–	10	24
Tegali	20	4	20	8	40	7	35	–	–	1	5
Hamar	392	191	48	18	4	2	5	19	4	162	4
Northern Jebels	15	–	–	8	53	6	40	–	–	1	6
Dar Hamid	41	29	7	2	4	–	–	7	17	3	7
Southern Jebels	83	3	3	14	16	23	27	11	13	32	38
KHARTOUM PROVINCE											
Khartoum Rural Council	135	42	31	27	20	3	2	21	15	42	31

TABLE 3.2 SITES STUDIED FOR 1969/70 PROGRAMME (cont.)

Province and Rural Council	Number of Sites Studied	Recom-mended for Boreholes	% of Total Studies	Recom-mended Shallow Wells	% of Total Studied	Recom-mended Hafirs	% of Total Studied	Recommen-dation not Specific	% of Total Studied	Not Recom-mended	% of Total Studied
NORTHERN PROVINCE											
Dongola	5	1	20	3	60	–	–	–	–	1	20
Shendi	106	40	37	15	14	1	.9	17	16	33	31
Merowe	32	11	34	–	–	–	–	–	–	21	65
Sukkot & Mahas	12	2	17	5	41	–	–	–	–	5	41
Berber	18	8	44	1	5	1	5	1	5	7	39
BLUE NILE PROV.											
El Kurmuk	8	–	–	–	–	8	00	–	–	–	–
Er Roseires	32	2	6	11	34	11	34	3	9	5	15
Rufas Sharq	25	16	64	7	28	–	–	2	8	–	–
Kosti	99	99	36	26	26	23	23	7	7	7	7
Abu Hugar	38	21	55	9	23	–	–	2	5	6	16
Sennar	94	54	57	22	23	1	1	–	–	17	17
Rufas Shukris	94	40	42	20	21	–	–	5	5	29	30
El Meilig	7	5	71	–	–	–	–	1	14	1	14
Northern Fung	54	28	52	13	24	3	6	–	–	10	16
El Hosh	43	12	28	22	51	–	–	–	–	9	21

TABLE 3.2 SITES STUDIED FOR 1969/70 PROGRAMME (cont.)

Province and Rural Council	Number of Sites Studied	Recom-mended for Boreholes	% of Total Studies	Recom-mended Shallow Wells	% of Total Studied	Recom-mended Hafirs	% of Total Studied	Recommen-dation not Specific	% of Total Studied	Not Recom-mended	% of Total Studied
DARFUR PROVINCE											
Eastern Darfur	99	8	8	-	-	-	-	58	58	33	33
Western Darfur	35	-	-	21	60	-	-	6	17	8	23
Northern Darfur	168	17	10.1	16	9	3	1	23	16	34	20.2
Dar Masalit	47	-	-	2	4	-	-	31	65	14	29
El Fasher	128	29	23	10	7	10	7	32	25	47	31
Southern Darfur	175	64	36	-	-	-	-	79	45	22	12
KASSALA PROVINCE											
Kassala Rural Council	34	15	44	12	35	-	-	1	3	6	17
Qala En Nohal	43	20	46	3	7	6	14	1	2	13	30.2
Southern Gadaref	192	105	54	1	.5	-	-	44	22	42	21
Northern Gadaref	201	41	20.3	7	3	50	24	29	14	74	36
Tokar	29	5	17	7	24	2	6	7	24	8	27
Amrar & Busharin	192	6	3	35	18	8	4	52	27	91	48
Aroma	119	6	5	63	52	5	4	8	6	37	31

NOTE: Data is given by provinces since at the time of the programme referred to (1969/70) regions did not exist. The divisions by province can be substituted for the present regons with Blue Nile Province becoming the Central Region, and Kassala Province, The Eastern Region; for the purpose of consistency with the maps Figures 3.1 to 3.6.

Devastation of Whole Belts. The discrepancies of land use planning at local and regional scales coupled with the absence of land use laws together with the increase in humans and livestock populations have led to severe degradation of whole belts. This is highly pronounced in the northern areas comprising the semi-arid belt where camel nomadism predominates.

The process of degradation of this ecosystem has followed a certain sequence. The extensive disease control programmes initiated in the later 1940's have increased the numbers of livestock tremendously. This development has facilitated the expansion of water-supply programmes especially after the mid 1950's reaching a climax in the mid 1960's. Water sources became the centres of attraction for large livestock concentrations. Apart from the general effect of the increased animal load on the natural resources around the existing water points, the pattern of grazing of camels and cattle operating from these centres contributed drastically to the spread of devastation to the vegetation cover in these areas.

Camels are able to graze at wide distances and have the ability to reach out to a number of water sources from the same grazing range. This led to the occurrence of large concentrations at any water point within a grazing zone. Cattle on the other hand are heavy graziers that cannot travel beyond 15 kilometers distance from water points. Most of the nomads of this belt have increased their cattle possessions creating a severe deterioration of the grazing cover around most water sources.

Furthermore, the availability of water has led to the rise of settlements at the source site or at proximity. Progressive settlement in this belt has been accompanied by heavy use of natural resources. The light nature of the sandy soils in the western region and its suitability for quick maturing varieties of millet have led to the clearance of large areas in the neighbourhood of water centres adding to the devastation already caused by grazing.

With time the carrying capacities of these marginal lands have begun to decline. The strained nomadic groups found an outlet into the savannah low rainfall belt from which they began a further southwards penetration into the Savannah High Rainfall Lands. Currently, camel nomads are found in the riverian lands of Bahr El Arab, Bahr El Ghazal, the White Nile and the southern reaches of the Blue Nile. This southwards infiltration is facilitated in part by the water sources provided in the intermediate belt between the northern and southern areas as from mid-1950's and on.

The pressure experienced at present by the water sources of the central and southern zones has increasingly built up due to factors other than nomadic infiltration. The vast development of planned schemes, being state owned or private enterprises, has expropriated large areas of land from under the traditional users. Examples include the massive areas brought under mechanized farming, the newly developed irrigated schemes, and the sugar estates. The development of these enterprises has led to the dislocation of the traditional users of the land, particularly the nomads who are being uprooted and forced to seek habitat in new areas. In the process the change has put additional pressures on the newly invaded territories.

The Damazin Company for Agricultural and Livestock Production can be taken as an illustrative example. The company is developing an area of 333,000 feddans in Blue Nile province with Saudi investment mainly.

> The impact of the project on the local population (settled and nomadic) can be viewed from many angles, under (i) immediate and direct effects on certain populations, (ii) deferred or future effects on other populations
>
> As for the immediate impact of the project it shall cause repercussions on the populations directly affected by it, estimated at about 53 thousand persons of whom 2 thousand are settled and the remaining 51 thousand are nomadic. As for livestock about 142 thousand animal units shall be disturbed.
>
> Pasture supply are the mainstay of the nomads and their livestock, needless to emphasize the fact that no sustained, stable and peaceful development of the Damazin project can be achieved without the concurrent and preferably the preceding allocation and development of separate and well demarcated areas for these people. Of the services that have to be given full consideration in this respect is the provision of adequate number of hafirs at the most suitable sites to maintain the ecological balance of the area and meet the grazing requirements of the different nomadic groups. (El Sammani 1982,)

Temporary Pressure. Temporary pressure is associated with two factors: maintenance problems and range failure. The former is felt at the micro-level of the water source, while the latter might affect a whole area or region.

There is a big discrepancy that developed with time between the provision of water sources and the maintenance of these sources. Up to 1966 this discrepancy was non-existent as the provision of water and the maintenance of supply centres were accorded equal weight. Maintenance was carried out by the same department providing water. In 1966 with the rise of the Rural Water Development Corporation, a new policy was adopted whereby the responsibility of maintenance was shifted to the local government councils. The Corporation would provide new water sources and hand them to the councils, which would run them, collect the revenue from sales of water, and supposedly maintain them.

With time it has become evident that this formula does not work, since the local councils are not equipped in terms of personnel or technical know-how to undertake this responsibility. Besides, the shortage in fuel in the last few years has magnified the running problems, especially of bore-holes. In time this has built up into a national problem and recently plans are being adopted to entrust the maintenance responsibility to the regional offices of the National Corporation for Water.

The break down of a water-yard or the failure of a hafir to fill induces the communities depending on it to look for alternative sources. This additional load on the source fetched is not limited to the extraction of extra amounts of water but often extends to putting heavy use on the natural resource base around that source. Though this phenomenon is a temporary one, if repeated, it leads in the long run to more lasting effects.

Range failure, which is mostly associated with low rainfall, generates pressure that can be of profound effect at an area or a regional scale. In both the semi-arid and the Savannah Low Rainfall belts the incidence of "mahal," i.e., bad rainy season accompanied by pasture failure, is of repeated occurrence in one out of every 5 years. When this phenomenon occurs, whole nomadic groups, as well as settled villagers owning large herds of animals, head for areas with adequate grazing where they spend the dry season. The effects of this on the grazing lands of the areas invaded become widely diffused.

It is evident that pressure on water sources is the result of many factors. In approaching the remedies to the problem all the issues raised have to be taken in totality. The planning aspects cannot be separated from the operational ones. Water provision cannot be taken per se independent of its impact on ecosystems, especially outside the irrigated areas. This emphasizes the need for adopting a resource planning outlook towards the question of water provision.

ADEQUACY OF AVAILABLE INFORMATION ON THE PROBLEM

Awareness about the positive and adverse effect associated with water provision is well established among the agencies directly involved with the tasks related to natural resource planning and management i.e., Soil Conservation, Range Management and Pasture, Forestry, the General Administration for Natural Resources, and the National Corporation for Water. The area of concern and emphasis is different from one agency to another; however there is a general consensus that the adverse effects ensuing from water provision are a direct outcome of the pressure building around water sources after they become operative mostly due to uncontrolled use.

The awareness extends to the public, especially at the professional level outside the 5 agencies listed above. This has been substantially fostered by the many scientific gatherings to treat issues emanating from the water question at regional and national levels.

The growth of this awareness is very much advanced by the built in scientific heritage in this field having its roots in the philosophies and approaches of the Soil Conservation Board and later the Land Use and Rural Water Supplies Department, The Soil Conservation Land Use and Water Programming, The Range Management and Pasture Administration, and The Forestry Administration. Though these units have failed so far to work in an integrated manner, the concepts of conservation and balanced use of natural resources are deeply entrenched in their outlook towards issues related to ecosystem planning.

Attempts to handle the question of pressure on water sources through more sound planning efforts can be cited. During the Soil Conservation period the idea of integrated Umudiva (subdistrict tribal unit) and village planning for optimum use of resources based on provision of water sources was considered and prototypes for certain ecological belts were designed. The same idea was revived by the Kordofan Special Fund project and by the Southern Darfur

Planning Survey. In realization of similar concepts, hafirs were designed with limited capacities so as to control the use of resources around them.

The limited size of the programmes of water provision implemented during the period of the Land Use and Rural Water Supply Department 1955-66 can be mentioned also although it led to the occurrence of pressure at the site level. However, it checked it at area and regional level. The research work carried out at Ghazala Gawazat in the later 1950's and early 1960's on range and pasture was aimed at improving grazing under natural conditions in the extensive savannah belt embodying concepts of balanced land use. However, little of that work yielded results outside the experimental yard.

The concern about village and town perimeters for protection purposes and for the supply of fodder and firewood requirements during the Soil Conservation period extending into the 50's and 60's. The efforts of more than one agency enlisted was another attempt to relate the provision of water to other uses.

Nomads settlement projects that aimed at organizing grazing based on optimum distribution of water sources according to carrying capacities can also be cited. Of the earliest projects in this field was the one initiated by Local Government in the early 1950's in Sinkat area in the Eastern region. Two other models were attempted, one in Babanusa-Muglad area in Dar Messeriya, and the other in Gireih El Saraha area in Dar Kababish. Some mistakes had accompanied the implementation of these projects. However, their visualization illustrates the concern about land use questions arising from the provision of water supply.

The Kordofan Special Fund Project for Land and Water Use Survey was carried out in an area of 90,000 sq. km. in north central Kordofan. In the period of 1962-66 it condensed all of the foregoing philosophies and experiences into the first attempt towards an integrated land use plan for a whole region with individual projects realized to serve the overall objectives of the plan.

> The Savannah belt of the Sudan covers about one-third of the entire country. A steep population increase, beginning early in the century, had resulted in over-cultivation and over-grazing of the usable land. Seventy percent in 1956 consisted of farmers and farmer labourers. Gum Arabic production was decreasing and soil exhaustion and erosion appeared imminent. To make matters worse the 10 million 1956 Savannah belt population was expected to swell to thirty-four million by 1996.
>
> The Government lacked the basic data, the trained personnel and funds required to counteract the increasing problems. On 13 August 1960 the Government therefore applied to the Special Fund for assistance in finding a balanced use of available land and water resources and delineating the zones best suited for livestock, gum acacia, mechanized and traditional cultivation methods (FAO/SF: 32/SUD, 1967, p. viii).
>
> Rising population has led to pressures on land use and on the drinking water supplies. ...The result is that pressures on the land resources are uneven. At one extreme there are places where the land

> is over cultivated and over-grazed. At the other extreme there are places which are empty. This uneven distribution of load means low productivity at both ends of the scale. ...The fundamental objective of development is to spread the load over the land resources as a whole and also to raise the productivity in all places and in aspects of land use.

The drinking water problem stands as a barrier in the way of this objective on two counts. First, there are stretches of empty land where there is no reasonable hope for providing water at acceptable cost by any of the customary methods, i.e., dug wells, or bore-holes, or hafirs, or small dams or by pipeline from major sources.

Second, a big proportion of people rely in the dry season on water transported from sources which are five, ten, fifteen or more kilometres distance. Water is carried either by animal or lorry. The cost is excessive either in cash for lorry transport or in effort by men and animal. So long as peasants have to carry this heavy burden there is very little hope of any substantial agricultural improvement. A real impact of up-grading existing peasant farming can only be made if the heavy cost of fetching and carrying water can be saved, and if the saving can be converted into productive uses. Drinking water sources are needed at each village so that the wasteful cost of transport can be avoided. However, there is one solution which is technically possible anywhere the empty areas, and that is to catch the rainfall and store it on the spot.

> Wherever drinking water is needed there is agriculture; whenever there is agriculture there is rain .... It was the prime objective of the project to find a practical solution on these lines at acceptable cost. The result was the "catchment tank" for which type-designs have been developed for units varying from forty or fifty thousand gallons down to a "family" unit of one or two thousand gallons. These type-designs are developed to suit the particular circumstances of the Project Area and are not necessarily suitable for other areas (Ibid. 8-11).

Whether the technological solution of "catchment tank" is practically applicable of not, the analysis of the situation leading to the conclusion drinking water supply is the decisive factor still holds true. On this experiment the Savannah Development Project and the Southern Darfur had followed:

> Rapid expansion of human and livestock numbers had severely reduced the carrying capacity of the land and the subsistence pastoral economy has been replaced by an agricultural one. Present social and political institutions are inherited from the subsistence economy, especially the system of land and water rights. In the presence of a stagnant primitive technology, rapidly expanding population and declining rainfall, the destruction of the environment is accelerating at an alarming rate. (Southern Darfur Land Use Planning Survey, Development Plan, 1974, p. iii).

> There has long been general agreement that the Savannah is overstocked. So far, the only politically acceptable way of reducing this pressure has been to open new water-yards in virgin areas. But unless this is accompanied by corresponding controls, the slack created is quickly filled. This is inevitable when protein is the principal constraint on the expansion of livestock numbers. Without controls the economic benefits of new water-yards are very short-lived. The ultimate control must be the closure of water-yards which are the focus of over-stocking. However, if this is to be feasible, land use plans must distinguish between areas allocated to grazing and those allocated to cultivation. Once cultivators have settled around a water-yard, the opportunity to use water as a tool of range management is lost. (Demoractic Republic of Sudan, Southern Darfur Land Use Planning Survey, 1974, p. 31).

Recent attempts pursuing this line of action deserve reference. The Desert Encroachment Control Programme is initiating activities that aim at restoring the vegetation cover in the northern and central parts of the country which are being affected by severe degradation. Questions related to organization of use of resources including water supply rank high as one of the priorities of this project. The Hashab Rehabilitation Programme aiming at the restoration of the Hashab cover in the habitat areas of Acacia senegal is another ongoing activity in this connection.

ACCURACY/GAPS AND RESEARCH REQUIRED

The above are dispersed efforts initiated at different times under the general awareness about the problem and the need to face it. They lack integration as can be judged from their nature and timing. In a recent paper by the writer on "The Impact of Water Supply Centres on Ecosystems with a Suggested Strategy for Action," I outlined the gaps in this area, pointed out the different shortcomings, and emphasized the future areas of action and research required. This is elaborated in what follows:

> Water programming should be approached in future in the context of ecosystems and not as a service to meet isolated needs e.g., adequate and hygienic supplies for rural communities, expansion of the agricultural production base, development of human settlements, and the like. Such targets, for a long time, dominated the philosophy and planning processes that guided water programming. Consequently, they emerged as the terms of reference of those government departments concerned with planning the utilization of ecosystems. Though most of these units claim that they realize the necessity of achieving balanced utilization of the renewable resources when they implement their projects, in practice the outcome is monolithic, adding to the confusion and stresses experienced presently by ecosystem.
>
> Therefore a new approach to water programming is highly needed, and now. This approach should embody one basic concept not given priority in the current planning of water sources: the control of

the use of the renewable resources through more comprehensive planning and monitoring of the ecosystems at the macro, meso, and micro levels. This will require adopting the following strategy of action, especially by the newly created regional governments:

At the Macro Level:

1. Develop land use plans to direct the usage of the renewable resources at the regional level.
2. Integrate the programmes of the units functioning at present in the area of renewable resources utilization, in accordance with the objectives set by the above plan.
3. Draft the essential laws and regulations which assure the effective usage of resources.
4. Train senior personnel in the field of ecosystem handling.
5. Increase awareness at all level (formal - informal) about the importance of maintaining balanced ecosystems.

At the Meso Level:

6. Apply zonation to ecological units with the purpose of defining different types of uses.
7. Initiate development projects based on the balanced utilization of ecosystems.
8. Build capacities of institutions dealing with ecosystems at this level.

At the Micro Level:

9. Develop village land use plans that aim at organizing the usage of the land resources around the villages, and to enable rehabilitating affected areas.
10. Introduce strict tenure rights so as to define village land property for different users, and as well meet the grazing requirements of the outsiders.
11. Specify kind of use for different water points i.e., strictly for settled population; for local villagers' animals, for nomads, for commercial livestock, etc.
12. Separate the water supply requirements for humans from that for animals, through effective distribution systems.
13. Adopt a system of alternating use of water points to enable the closing down of those centres which show signs of deterioration of the ecosystem.
14. Involve the local communities in the planning and running of the water points and in the management of the ecosystem affected by them.
15. Re-educate the local leadership and the village communities in management aspects.
16. Raise the water prices and use the revenues generated in financing ecosystem management projects.

17. Improve the maintenance and the running of water-yards through further decentralization of the regional and subregional maintenance centres, to enable this service to function effectively at village level.
18. Work towards diffusing maintenance technology to be assimilated in time as part of the local technical know-how.
19. Up-grade the prevailing traditional economies through improved inputs to raise the levels of production so as to meet the basic requirements of the population; i.e., food, fodder, firewood, charcoal, etc.; which consequently leads to improvements in the standard of living of the total population.

The realization of the above strategy would require among other things, a strong research input. Areas that are considered of priority in this respect are:

1. An overall evaluation of the present water supply situation by area; preferably by administrative units (regions and area councils) rather than by physical zones (geological formations, vegetation belts, etc.) to relate the available supply to population requirements, to deficit, and to future potential. In examining potentialities, research should be directed to surface water sources (rain storage, seasonal water-courses and the perennial ones) and to ground water to determine acquifer behavior. Special effort in relation to the latter should be devoted to geophysical investigation in the Basement Complex areas where so far the resources discovered are of very limited occurrence.
2. Examination of the water resource potential should be carried out in the context of natural resource bases, taking into consideration the present and future needs of the socioeconomic development of the population. This would require inventories of the natural resource potentials, and study of the human and livestock population trends and distribution. Elaborate quantification of these obvious parameters plus others is essentially needed, besides of course the related basic map work. Schemes of data collection; storage and retrieval should be developed, to enable the monitoring of change. The data available is outdated and lacks uniformity. Therefore, systematization and standardization of information should be accorded priority in future researches.
3. Issues related to the integration of sciences in the fields of natural resource planning, use, and management with the purpose of harmonization of the task areas of different concerned units, deserve full investigation. A scheme should be designed to address the question: how to unify the philosophies and integrate the activities of those units presently engaged in the mentioned fields; not only that, but how to structure units that have viability at area and regional levels should also be considered. The essence for integration is highly held but not transformed into workable mechanisms. Research in this area should give attention to examining the present scope of activities of

the concerned units, should beg questions related to the organizational and managerial capacities, and focus on the training requirements both formal and informal.

Due to the problems of finance and personnel limitations, it might not be feasible to commence on country-wide research programmes at one time. Therefore priorities have to be worked out with more attention given to the needy areas where, so far, the customary methods of water provision have failed to furnish reliable supplies. Even those can be categorized by assembling areas of similar nature under one category, and carrying out piloting programmes at each.

The scheme outlined above may not be easily implemented as it is conceived. Many obstacles can be immediately spotted. To mention a few examples, there is the complete or partial lack of understanding of policy-makers, as well as many of the technical people of how ecosystems function. To re-educate both is a matter which is resource and time consuming. The problem is further aggravated by the all-the-time-present competition over the limited available resource, between urgent needs and those that can be deferred for sometime. Unfortunately ecosystem planning falls under the category of the latter. Definitely there is also the impact of the local politics which can scale priorities in such ways as to match immediate gains, which may again work against integrated land resource planning at all identified three levels. The nomadic tribes shall be among the first population groups to be affected by the implementation of any control measures and in response are expected to react strongly against any kind of land use planning. Over and above, there is the important question of the availability of the means to implement such a strategy, being finance, technical know-how, personnel or equipment.

Despite all above repercussions, a start should be made, since the only foreseen alternative is more devastation of ecosystem. (El Sammani 1982, 43).

CHAPTER FOUR

Chapter 4 examines the problem of deforestation in Sudan. Deforestation is the result of three important agents:
1. agricultural expansion;
2. burning to create grazing pastures;
3. the use of inefficient methods in the production of charcoal.
The problem is currently growing more severe throughout most of Sudan and, unless immediate action is taken, may result in a national crisis especially in the energy and agricultural sectors.

The solution of the problem for all of the region requires the development of a sound natural resource use policy. The policy should recognize that forests are part of an ecosystem and attack the problem in a holistic, cultural-ecological fashion. Only through such a policy can the deforestation problem be adequately managed with benefits accrued to the proper beneficiaries--the local peoples whose livelihoods depend on a self sustaining resource base.

Deforestation Resulting from Clearing Land for Agriculture, Grazing Pastures, and Charcoal Production

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INTRODUCTION

In this paper "deforestation" will mean removing trees whether they are found in forests or scattered to form a partial cover for the soil or other resources. Trees are removed for various purposes such as clearing land for agriculture or grazing, production of fuel wood, or for use in construction.

Does deforestation create a problem? The answer is, of course, yes. The problem is created by stopping the function or functions that trees perform. These functions differ from one region to another, and so the severity of the problem differs according to the region. These differences or magnitudes of the problem are augmented by climatic factors, i.e., geographical differences, and by human attitudes towards trees as a resource, i.e., cultural or educational differences.

This paper will outline the problems of deforestation by following the distribution of tree species in each ecological region of the Sudan. The functions of different tree species will be discussed, as well as the problems created by their removal.

Among those who have studied Sudan's flora are Brown (1928), Brown and Massey (1929), Andrews (1948), Smith (1948), Harrison and Jackson (1958) and El Amin (1982). Most of them have produced plant distribution maps. The simplest of these maps and the most relevant to this discussion is a series of maps produced by Smith (1948). These maps will be used to define the magnitude of deforestation in each region.

The Sudan is divided, at present, into seven political regions. While the main discussion will centre on the ecological regions, reference will be made to these political regions when severe problems of deforestation or remedies are discussed.

Deforestation constitutes a national problem for Sudan. It affects the whole country without exception. If the effects of deforestation are not felt by some people, it is only because of the lack of awareness and education about the process of deforestation. Because of this lack of awareness, some parts of the Sudan realized the problem only when it was too late; when the area had lost most of its tree cover, e.g., the Eastern Region and especially Kassala Province.

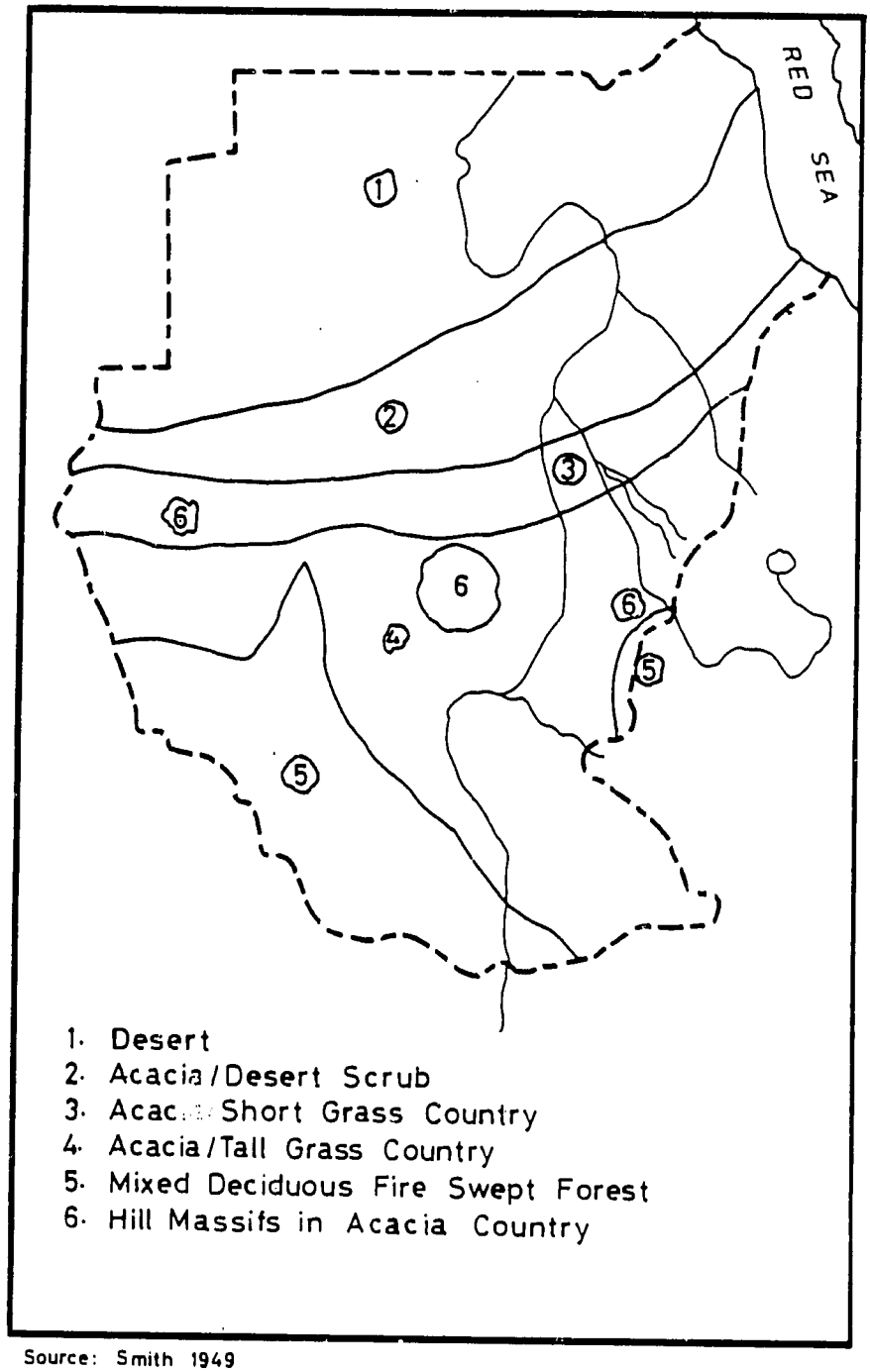
The solution of the problem for all of the region requires the development of a sound natural resource use policy. The policy should recognize that forests are part of an ecosystem and attack the problem in a holistic, cultural-ecological fashion. Only through such a policy can the deforestation problem be adequately managed with benefits accrued to the proper beneficiaries -- the local peoples who livelihoods depend on a self-sustaining resource base.

Figure 4.1 shows the principal ecological formations of tree vegetation in Sudan. This map was prepared by Smith while he was studying the distribution of tree species in Sudan in 1948. Superimposed on Smith's map are maps of the political regions referred to earlier, soil types, and population distribution, Figures 4.2, 4.3, 4.4 and 4.5.

THE DESERT

This area covers the Northern Province of the Northern Region, North Darfur and the northern part of the Eastern Region. As rainfall is rare, trees are found in seasonal streams that pass through the desert on the banks of the

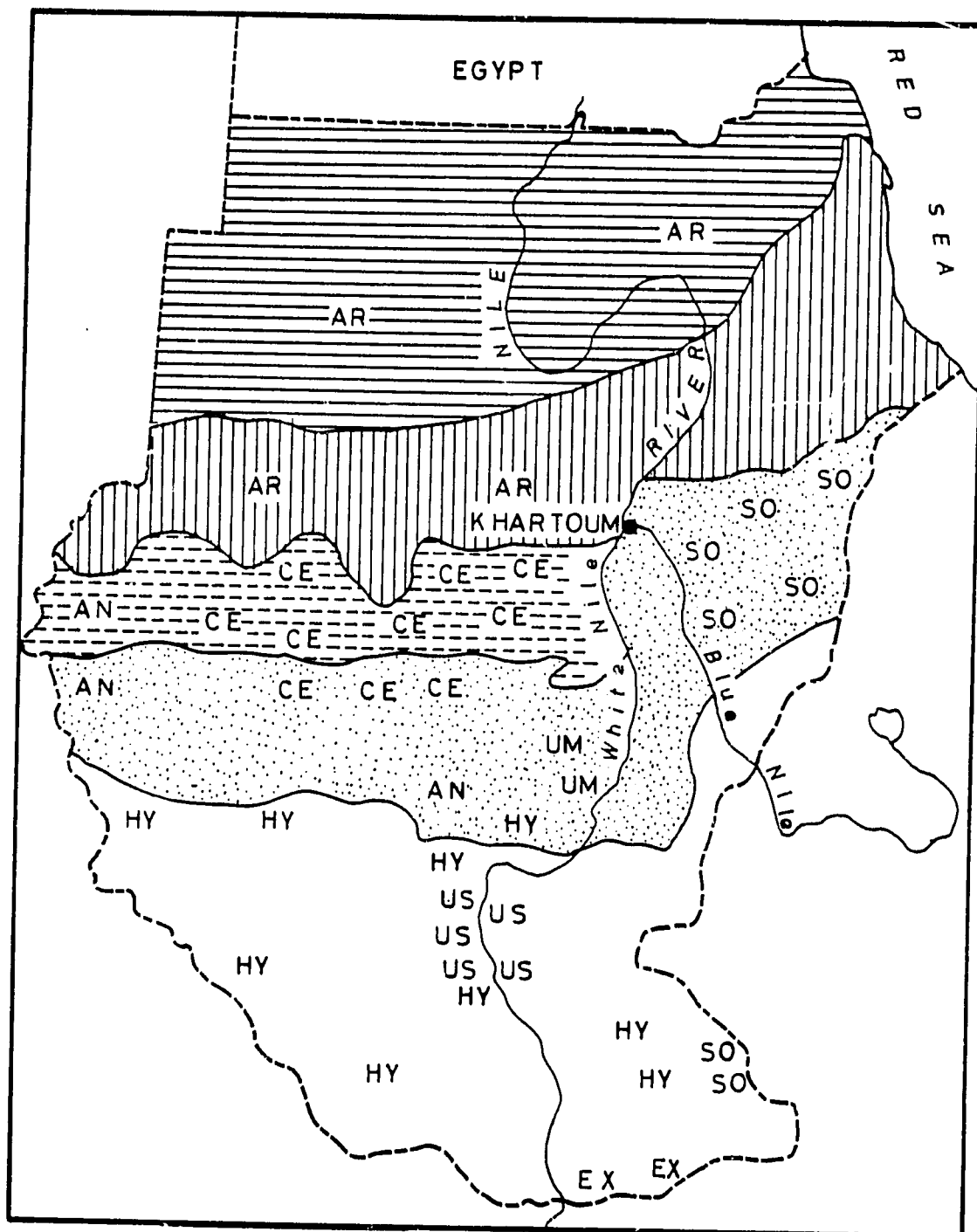
PRINCIPAL GEOLOGICAL FORMATION TREE VEGETATION



Source: Smith 1949

FIGURE 4.1

IMPORTANT GRASS COVER TYPES AND DESERTIFICATION CLASSES
BASED ON RANGE CONDITION CLASSIFICATION



DESERTIFICATION CLASSES

Desert

Severe

Moderate

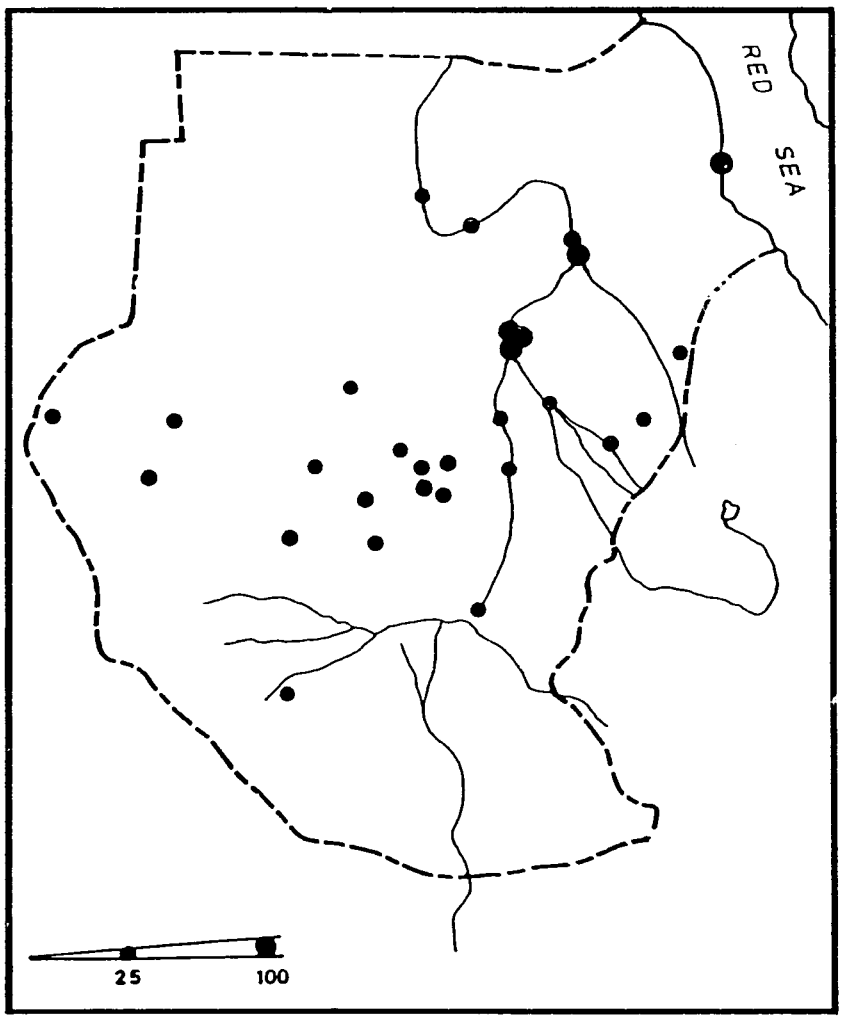
Light

FIGURE 4.2

GRASS COVER TYPES

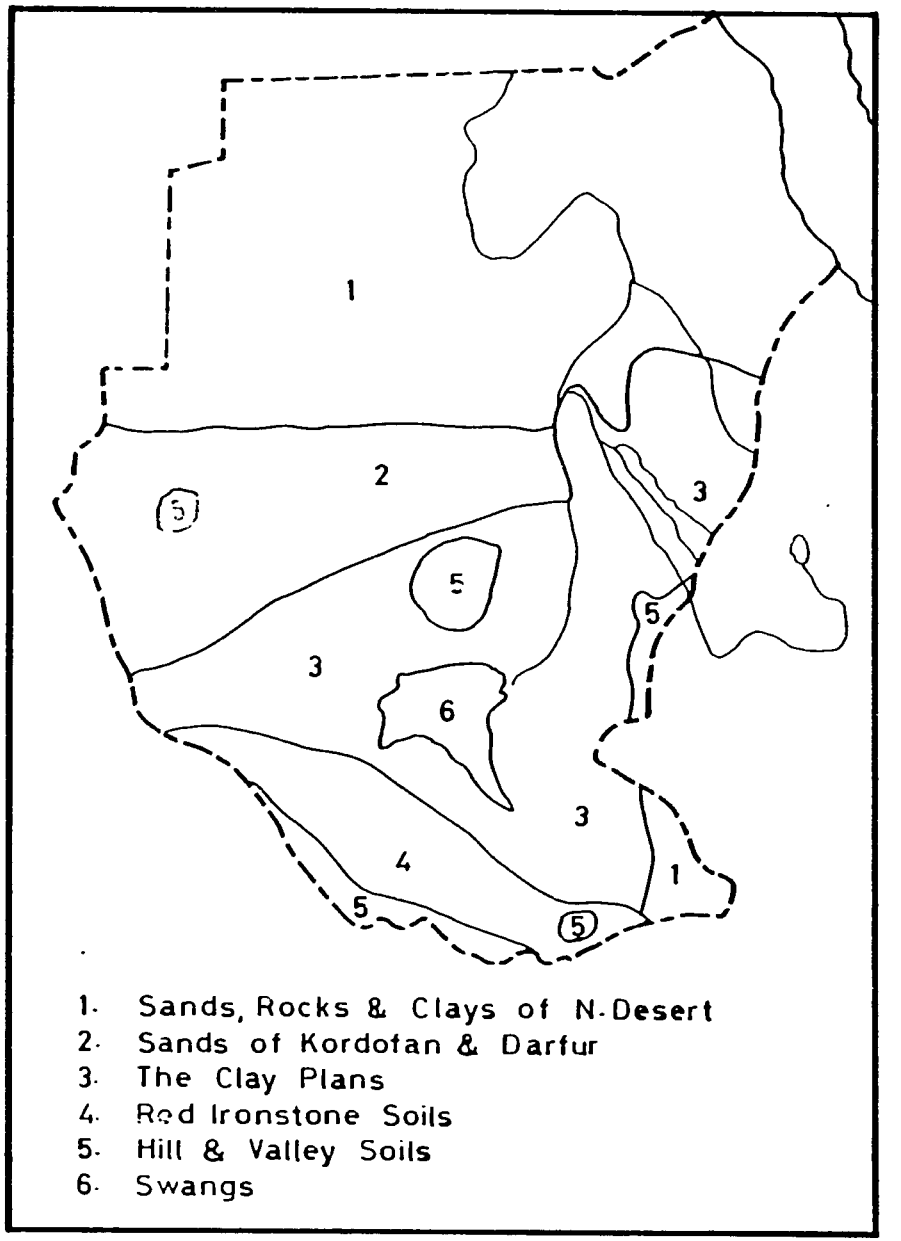
Aristida	AR
Andropogon	AN
Cenchrus	CE
Sorghum	SO
Hyparrhenia	HY
Swamp	US
Montane	UM
Exotheca	EX

FIGURE 4.3
DISTRIBUTION OF POPULATION



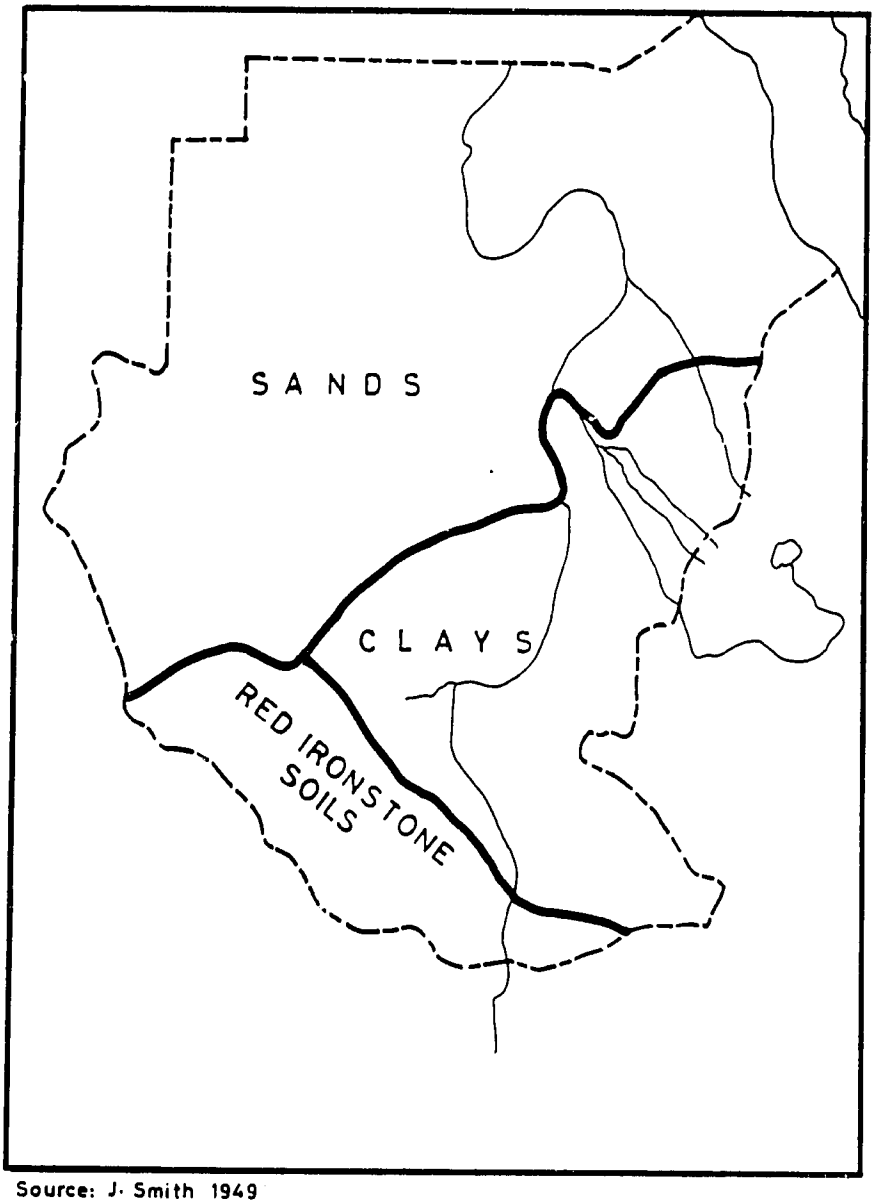
Source Geography of the Sudan 1981

FIGURE 4.4
PRINCIPAL SOIL TYPE & THEIR APPROXIMATE DISTRIBUTION



Source Smith 1949

PRINCIPAL BOUNDARIES OF SANDS/CLAYS & RED IRONSTONE SOILS



Source: J. Smith 1949

FIGURE 4.5

main Nile and the depressions or basins near the Main Nile, e.g., the Kudruka Forest, the Birkat El Muluk Forest and the Kudi. The main tree species in the desert runnels are the Acacia tortilis var. tortilis, Acacia ehrnberoiana and Tanarix aphylla. The major tree species in the Kudruka and the Birkat El Malak Forests are Acacia nilotica and Acacia seyal. On the banks of the main Nile Acacia albida, Tanarix nilotica (syn T. articulata), Zizyphus spinachristi & Hyphaena thebaica are found. All these trees, whether in stands or scattered, suffer from severe felling to the extent that wood has become one of the most expensive commodities in the region. Wood in this region is also more expensive than in any other region in the country.

The consequences of deforestation are manifested in sand encroachment on buildings, farms, roads, the railroad, and canals. This encroachment has created a rather formidable constraint to development.

Arable land in this region is confined to the river banks. It is exposed to sand encroachment on the desert side and to gully erosion on the river side. At the same time human and animal populations are increasing rapidly. Attempts to use lands farther away from the river using groundwater for irrigation are hampered by sand blowing on the crops and canals. In fact, flying over the desert one can see abandoned farms representing such attempts.

Causes and Corrective Measures.

Causes. The causes for deforestation in this zone were and remain the felling of trees for timber and fuel to meet the population's needs; and the felling of large areas of forests (Kudruka and Birkat El Malak Forests) to clear land for agriculture.

The information available on wind hazard is quite adequate. Hummocky lands become difficult to irrigate and therefore are mostly unproductive. Gullied areas suffer loss of land and property, i.e., houses, date palm trees, and pump sites. As lands were fairly accurately mapped, losses are also accurate.

The corrective measure for this zone is to plant trees as shelterbelts to reduce the effects of wind and hence reduce or arrest sand movement. These shelterbelts could also provide fuelwood and timber for the population. Shelterbelts have been introduced as a research project near Dongola and near Ed Damer. Shelterbelts were not used in the past because their benefits were not widely known. Land fractionation and land tenure were also causes for not planting tree shelterbelts as tenants or farmers were not necessarily the land owners.

Implementing the corrective measures.

The corrective measure being undertaken is the planting of tree shelterbelts to protect the land and to provide fuelwood and building material for the region's population. Institutions carrying out the corrective measures are:

1. The Forests Research Center;
2. The Forests Administration;
3. The Sudanese Council of Churches (SCC).

Little has been done to correct the situation to date. Although little has been done, the projects undertaken have been done well. The Forestry Research Center has established an arboretum near Ed Damer where more than 35 tree species were planted and the provenances are now over ten years old. From these trees the Forests Department can select trees for large scale plantations to satisfy the local needs. The centre has also established some shelterbelts and is monitoring their effects on crops and protection of irrigated canals.

The Sudanese Council of Churches (SCC) has done an excellent job during the last five years in the Nile Province. This organization has established Eucalyptus and Prosopis shelterbelts around irrigated agricultural schemes. This has been done to protect these schemes from sand encroachment and to provide the local population with timber. The SCC holds yearly seminars to demonstrate to farmers the beneficial effects of tree shelterbelts. About 20 farmers, selected through the farmers union, spend one week at a school dormitory listening to lectures from foresters, researchers and agronomists. They attend slide shows and films on conservation and take field trips to the shelterbelt areas. Each farmer receives a certificate of attendance at the end of the seminar. This extension and adult education work has proven to be extremely effective in winning the case for forestry among farmers. The work of the SCC is appreciated at all levels and the Government of Sudan has requested that SCC extend their work into the Northern Province.

The Forests Administration mainly reserves forests, establishes nurseries for restocking forest reserves, plants woodlots and carries out conservation measures. Near Dongola, the Forestry Research Center in collaboration with the International Development Research Centre of Canada (IDRC), has a research project called "Land Reclamation in Kerma Basin". One of the main objectives of this project is to identify the most useful type of shelterbelts, i.e., 2-row, 3-row, 4-row, or 5-row. These shelterbelts were planted in very exposed areas in a desert basin. The micro-climate behind these shelterbelts was continuously monitored for five years.

Constraints to Implementing the Corrective Measures. There are several constraints to planting trees in this region. The main constraints are:

1. Land. Most farmers in this region have small holdings so they are reluctant to plant anything besides their usual crops.

2. Land Tenure. Tenancies in this region often change from year to year. Therefore tenants do not want to plant trees which cannot be harvested during their tenancy.

3. Water. In large agricultural schemes, farmers are charged for the water they use during the season. There are established rates which charge the user per acre per season for annual crops. No such water rates exist for tree crops, as they are not annual crops.

4. Cost Recovery. In some areas water is lifted by pumps using gasoline or diesel fuel which is bought at high prices. Farmers can recover their costs at the end of the growing season when they sell their

crops. With trees they could not recover their costs for many years. Since trees do not bring an immediate return, farmers feel that planting them is not such a good investment.

5. Management. Agricultural inspectors in the field, sometimes do not want to bother with continually inspecting tree plantations, so they do not especially encourage farmers to plant trees. Few inspectors seem to understand the benefits of shelterbelts.

The degree of local participation has increased but only very recently, after interviews, extensive education and demonstrations that farmers have started to take an interest in tree planting. In the Dongola area when farmers saw the effects of shelterbelts, and how they helped to control sand creep and created comfortable working conditions, they started asking for seedlings and planted shelterbelts for themselves.

ACACIA-DESERT SCRUB AND ACACIA-SHORT GRASS REGION

This region includes the Nile Province, Khartoum Province, Central Darfur, most of Kordofan, the Central Region and the Eastern Region.

This ecological region has been divided into several subdivisions according to soil type and land forms (Harrison and Jackson 1958). Since this paper concerns itself with tree flora, J. Smith's maps will be used to delineate this region (see Figures 4.2 and 4.3).

The major species in the northern part of this ecological region are Acacia tortilis, Maerua crassifolia, Commiphora africana, Acacia mellifera, Acacia nubica, Capparis deadua, Calotropis procera and Leptadenia pyrotechnica. In general the distribution of these trees and shrubs is influenced by land forms that affect moisture distribution. The whole habitat is either water-receiving or water-losing with the trees growing in runnels while the inter-runnel ground stays bare. Other tree species such as Salvadora presica, Dubera alba, and Balnites aegyptiaca occur in small localized areas that are difficult to map.

In the southern part of the region there are Acacia mellifera on the clay soils. In addition to these species, Albizzia sericocephala, Albizzia asylmeri, Commiphora africana, Scierocaria birrea and Combretum heartmanianum are also found while Adansonia digitata and Terminalia brownii grow on sites receiving more moisture than the annual rainfall of the region. On seasonally flooded lands near the River Atbara pure stands of Hyphaene thebaica are found.

Causes and Corrective Measures.

Causes. This ecological region has suffered much deforestation from clearing land for agriculture, overgrazing and overcutting for fuel and timber needs. Specifically large areas of land were cleared:

1. in the Nile Province for the El Zeidab, El Aliab, and Kelly agricultural schemes;

2. in the Khartoum Province for several agricultural schemes;

3. in the Central Region for the Gezira, Kenana, Geneid and several schemes on the Blue and White Nile;

4. in Kassala Province for several Mechanized Crop Production schemes;

5. in Gezira and Kassala Province for the Rahad scheme; and

6. in Kordofan and Darfur Provinces for traditional agriculture.

Agricultural activities, whether irrigated or rainfed, have contributed to overgrazing problems. As more areas are taken up for growing crops, herders have been squeezed into smaller areas for grazing. The overgrazing has reduced or prevented tree regeneration. This ecological zone also contains most of Sudan's population (Figure 4.3), therefore the demand for timber and fuelwood is very high and has lead to deforestation.

Adequacy of Available Information on the Problem.

The deforestation problem has become very evident by the lack of tree cover, the shortage of timber and fuelwood in the region, reduced grazing areas for animals, and growing signs of desertification such as dust storms, gulley erosion (kerrib), floods and lower yields of crops (Ibrahim 1978). All of these situations are so obvious that they constitute problems in their own right.

There are several areas where additional information and research are needed. The exact requirements for timber and fuelwood for the region's population are not known. Furthermore, it is not known whether the present tree cover and species can meet the needs of the population, and perhaps exotic species will need to be introduced and tested.

Issues such as the economical design of homes to conserve timber, and treatment of timber against insects, fungi and other pests also need additional study.

Corrective Measures to Eliminate or Reduce Causes and/or Problems

The main causes for deforestation were identified as agricultural expansion, overcutting and overgrazing. The solution of this problem rests with rectifying these practices.

Land cleared for agriculture can be compensated for within the agricultural scheme. Natural stands are thinly stocked, i.e., 50-60 trees per acre (120-144 trees per hectare). The number of trees removed can be replaced with closely spaced tree rows in the form of shelterbelts or windbreaks. This is quite possible in the irrigated schemes and in the rainfed Mechanized Crop Production schemes. These large schemes could actually grow double the number of trees cut without losing much area for growing crops. Growing trees on agricultural schemes would have an additional benefit of improving the

micro-climate. Trees could also be sold profitably for firewood. Firewood sells for £ 45.000 per stacked cubic meter in Khartoum.

The problem of overcutting can be solved by knowing the consumption of timber and fuel, and by knowing the allowable cut. The deficit between the consumption and the allowable cut could then be met by reserving large areas of forests and using fast growing indigenous or exotic tree species. Importing timber and fuel (kerosene) from other regions could also reduce the pressure on the resource. Lastly, laws and regulations against the use of the resource in the presence of an alternative should be enforced. Here extension education and legislation can be combined to protect the forests.

Animals normally enter forests for shade, fodder, and water. In many forests of Sudan, whether natural or artificially regenerated, there is much fodder. Rational and controlled grazing can be beneficial since it reduces fire hazards. However, overstocking of animals in limited areas can be harmful to the soil and to the regenerative capacity of the trees. Shepherds in Sudan used to set fire to grasses to improve the feed. These fires would kill young trees and tree seeds. What is needed to reduce and eliminate the problem is controlled grazing calculated according to carrying capacity and avoiding forest areas with young regeneration.

A serious problem for which corrective measures have not been taken is the lack of a resource-use policy and lack of forestry education among planners. In the absence of such a policy, agriculture has expanded without direction. Agricultural expansion is justified because it produces food, it is short term (annual) and has a quick return. These are the flags politicians wave during election campaigns. As forestry is a long term programme and less labour intensive, it is not popular with politicians and decision-makers.

There is a forests policy and there are forestry laws. However, in the absence of a policy for other resource users, the forest policy has been difficult to implement. Therefore, combined efforts to care for all natural resources do not exist.

Resource and consumption assessment are the corrective measures presently being undertaken. The Forests Department through the Food and Agriculture Organization obtained the services of an expert to establish a Forests Inventory Section (Francis 1960), to assess the amount of resource needed for railway sleepers, and to start a nucleus for a national forests inventory. The work of the expert ended in 1960, four graduates and three technicians were trained, but the systematic forests inventory was not done. Now in 1982 the same Forests Department is seeking aid to strengthen the Section and to carry out the national inventory of the forest resource. The Forests Department in 1962 requested the Food and Agriculture Organization to help in the assessment of timber requirements and to prepare a forecast for future requirements (Saini 1964). Dr. Saini's findings included a per capita consumption of $1.6m^3$ in 1964, and a forecast of $1.67m^3$ in 1971 and $1.93m^3$ in 1981. Based on Dr. Saini's forecasts and a population estimate at 20 million in 1982, the present consumption will approximate 38.6 million cubic meters.

The Forests Department, now 80 years old, reserves land for forests, plants trees on the reserved areas, protects lands proposed for reservation, produces sawn timber and fuelwood for the Government and the private sector, and performs reclamation work such as combating desertification. The Forestry Research Center is doing research on tree species useful for afforestation efforts, reclamation methods such as shelterbelts and sand dune stabilization, and on indigenous species and their suitability for fodder, fuel and conservation. The Department of Energy is a new agency and its main objective is to ascertain fuel resources, fuel consumption and efficiency of different types of stoves, etc.

Although the institutions mentioned above work hard, little is accomplished. The Forests Department has set as its target 15 percent of the area of Sudan to be reserved in forests. To date the total area that has been reserved is less than 1 percent. Of this one percent, less than 20 percent has been stocked by tree planting, and less than 2 percent is managed in a scientific manner. Sawn timber and fuelwood production are accompanied by a large percentage of waste, mainly due to obsolete technology and wasteful methods of conversion. The Research Center's activities have been limited by a shortage of personnel and financing. The Energy Department has conducted fuel consumption surveys in certain parts of the Sudan.

The major constraints to implementing corrective measures are lack of an integrated natural resources use policy, lack of trained personnel, lack of financing, and statutory and customary constraints. Forest Policy was laid down in 1932 and a Forest Law was passed in the same year to implement this policy. After fifty years of hard work the results obtained have not been satisfactory. This is mainly because other resource users (farmers, pastoralists, timber and fuelwood merchants) kept restricting the implementation of this policy. It is high time to formulate a resource use policy wherein each user understands and respects the laws that govern the use of the resource. This should be followed by a plan to develop the whole resource in which forests will find a place among farms and pastures, and where reservation of new lands will be paramount. A resource survey should be carried out to ascertain all resource potentials rather than a forests inventory alone.

The second constraint to implementing corrective measures is the lack of trained personnel and extension education. Without the trained staff who know their silviculture very well, trees will continue to disappear for various reasons. Furthermore, other resource users, especially farmers and pastoralists, must have a fair degree of knowledge about the effect of trees on their habitat. It is only in the last five years that forestry curricula have been introduced in the universities of Sudan. Extension efforts among administrators and farmers have also been lacking.

In Sudan, lack of finance has been and will be a constraint for several activities. For forestry development this problem is compounded by the fact that controllers of finance do not understand forestry. When budgets are tightened the financial controllers cut or drastically reduce funds for vital forestry operations, such as fire lines. As a result fire lines were not maintained and fire broke out which destroyed valuable plantations in Jebel Marra,

the Imatong Hills and other areas. Lack of finance also curtailed the execution of several planting and reservation programmes. At the same time, finance has always been available for cutting trees for railroad sleepers, sawn timber and fuelwood. Throughout the history of the Forests Department the Utilization Section has had a much larger budget than reservation and afforestation programmes.

This Utilization Section contains all groups of sawmills. Each group of sawmills has a battery of loggers, lorries, tractors and light cars. Their main work is to cut millable trees to supply railway sleeper and other kinds of sawn timber and fuelwood from off-cuts. Larger budgets for machines, machinery fuel and personnel are allocated to this section because the return is immediate. Forestry activities such as planting, tending to existing plantations, protection and reservation are long term investments and so they suffer cuts.

Revenue from the sale of timber, fuelwood, taxes on charcoal, etc. are not available to be used directly on the forestry operations. This money goes directly to the central treasury. The idea of a forestry fund was suggested by the Forests Department, but was rejected. Moreover, in the forest rich areas (i.e., Blue Nile Province), forest revenue pays most of the government salaries. When decentralization took place some foresters tried hard to keep the forests administration centralized. They were concerned that regional governments may try to use the revenue from forests for other activities which could lead to resource depletion.

The institutions responsible for the forest resources were and still are severely understaffed. Until 1975, the staff in the Forests Department and the Forestry Research Center were as follows:

University Graduates	35
Trained Technicians (G.C.E. & Forest College)	181
Technicians (in service training)	57
Forest Overseers (can read and write)	239

This data is quoted from a booklet prepared for the First Agricultural Conference in 1975. This same reference mentions that there is a drastic shortage of university graduates and trained technicians. It goes on to say that if the Department is to execute its duties properly it needs to acquire 15 graduates and 40 technicians annually.

The law gives powers to the Director of Forests to conserve and prevent cutting of forests, yet the Director of Forests cannot stop land clearing for Mechanized Crop Production Schemes. Through several constraints, the Director of Forests cannot plant equivalent areas of trees felled for Mechanized Crop Production. The Forests Department cannot even salvage the timber felled from those schemes because the land is cleared by mechanical means (tractors, chains, etc.) while all afforestation methods are still manual.

The Mechanized Crop Production Schemes are administered by a corporation that plans the sites, size of scheme and renders some services to farmers who pay special rates per season. There are also unplanned Mechanized Crop

Production Schemes that are outside the purview of the corporation. Those farmers do not receive services of the corporation but they can fell trees in areas similar to those of the planned schemes. These farmers have their own union and are quite influential in the region.

It is only in the past ten years that the local population has felt the danger of deforestation. The rise in prices of timber and fuelwood, and their relative scarcity have made the people concerned. The extension education campaign following the drought and the appearance of signs of desertification have made the population more aware of the deforestation problem. Some people have responded to this by guarding forests in their neighborhood against felling (e.g., Sheika El Siddiq - Central Region), and in some areas people have planted village forests (e.g., the Village of Birush in Darfur Region). Others have participated in reclamation work, for example the El Bashiri Sand Dune Fixation Project in the Kordofan Region.

ACACIA TALL GRASS REGION

This ecological region includes the southern part of the Eastern Region, the Central Region, Southern Kordofan, Southern Darfur and more than half of the Southern Region. Its soils are predominantly clays. The topography of the area is a flat plain with only the Nuba Mountains and Ingessena Hills as high ground. The grass is 1.5 - 2.7 meters high and consists principally of annuals, of which the dominant species are Adar (Sorghum sp.), Annis (Sorghum sp.) and Anzora (Hyparrhenia sp.). Annual fires rage across this whole vast area interrupted only by water courses, rocky hills or temporarily grassless areas.

This large region comprises nearly one third of the area of Sudan, yet only five tree species share dominance on this clay plain. These are Acacia mellifera, Acacia fistula, Acacia senegal, Acacia seyal and Balanites aegyptiaca (Smith 1949). Acacia seyal is the most common tree and is dominant over the greater part of the Acacia tall grass region. The hills carry the following tree species: Lonchocorpus laxiflorus, Stereospermum kuthianum, Sterculia setigera, Anogeissus schimperi, Boswelia papyeerifera, Ficus sp. and Oxytenanthera abyssinica.

This region is traversed by the Blue Nile and its tributaries, the Rahad and Dinder Rivers, as well as the River Atbara and the Sobat River. The Blue Nile is surrounded by a chain of annually flooded basins carrying pure stands of Acacia nilotica forests. The ox-bow lakes of the River Atbara carry thickets of Zizyphus spinachristi. The rainfall of this ecological region ranges between 450mm in the north to 800-900mm in the south.

Causes and Corrective Measures.

Magnitude and Role of Change. Satellite images taken ten years ago, when compared with those taken in 1981 show the intensity of agricultural activity

in the zone. This trend is increasing each year as roads and settlements develop, and as clearing technology advances.

Causes and Relative Importance of Each. Deforestation in this region is caused by mechanized and traditional farming practises, fires, tree cutting for charcoal production, overgrazing and industry. Dr. J. Smith who was the Director of Agriculture and Forests stated in 1949 that, "The vast pure stands of Acacia seyal growing on rich dark cracking clays form the principal feature of 'Acacia Tall Grass Country'. These rich soils produce in cultivation heavy crops of sorghum, millets and sesame and represent an agricultural asset of the highest importance to the country and of no little importance as future sources of grain for certain world markets" (p. 14).

In the days of Dr. Smith, the clearing of bushes and trees was done manually. With the introduction of tractors, crawler tractors and chains, large areas of land have been easily cleared. The minimum size holding in the Mechanized Crop Production Schemes is now 1000-1500 acres and those who have the means are not limited by number of holdings. If the government does not plan an area for Mechanized Crop Production, the farmers can clear any area outside the Mechanized Crop Production areas. The trees felled are normally burned to ashes, since farmers do not have time to wait for the Forests Department to transport or salvage the felled timber.

The list of crops Dr. Smith referred to in 1949 was short. Now the cracking clays are producing cotton, sugar cane, sesame and groundnuts. The forests of Acacia seyal are being reduced and may be doomed. Acacia seyal is an indicator tree for these crops, so as the infrastructure for agricultural production develops, the forests will fade away.

The Mechanized Crop Production Schemes do not enforce crop rotation nor do farmers in these schemes apply fertilizers. Once the yields drop, the farmers shift to another area to cultivate. These areas damaged by shifting cultivation are becoming very large. Large barren areas can be seen in Agadi, Garabin, Dali and Mazmoun. These areas are now under reclamation after overcropping. This damage has been most severe in the Eastern Region and Central Region. Now similar problems are beginning to develop in the Darfur and Kordofan Regions.

This region with its tall annual grasses is extremely susceptible to fires. In fact, most ecologists regard Acacia seyal as a fire climax species. Air photos and satellite images show the effects of these fires. Fires burn the seedlings and the seeds, and reduce the stocking very drastically.

The causes of fires are many. Farmers set fire to the grass at the start of the rains so that the fires burn the weeds. This reduces the cost and time for weeding. These fires are not controlled and often run wild and damage forests. Pastoralists set fire to the grass at the end of the rainy season. The new flush after burning is more palatable to their animals. Hunters, honey collectors, smokers and charcoal producers also play a part in these fires.

Acacia seyal is found in pure, well stocked areas in this region. The trees are more or less of even age and are about 13 cm in diameter. This makes

them an easy tree to fell. When burned Acacia seyal produces excellent charcoal. The tree's characteristics make charcoal production very profitable. Illicit charcoal producers have gone deep into these forests, away from the main roads to fell their trees. From an aircraft one can see the amount of scattered clearing that is going on. The development of all season roads is definitely increasing the charcoal activity. The demand for charcoal is insatiable in Sudan. Converting wood to charcoal wastes nearly 85 percent of the energy in wood. As other sources of energy are not accessible for most of the population, charcoal will remain the main fuel source in the near future.

Grazing animals form an important element in the economy of the region. As grasslands are a dominant feature, raising animals shares this dominance. The encroachment of agricultural activities on pasture lands has led to concentrating animals on smaller areas. When such areas happen to carry trees, then their regeneration is hampered by overgrazing. Shepherds also fell and lop trees for their animals, and they set fires to encourage regrowth of fodder.

Some tree species in the region have attracted industry. Boswellia papyrifera is felled for making matches. Balanites aegyptiaca is felled for the bentwood industry. This in addition to the local use of timber for beds, housing and other cottage industries.

Adequacy of Available Information on the Problem. There is very little data available on the stocking and standing volume of the natural forests in the region. Rough estimates (Jackson 1960) made twenty years ago are no longer valid. The rate of agricultural expansion, the damage caused by fires, the rate of tree growth and recovery are not known. Research is needed to ascertain the total impact of these practises on the region.

Corrective Measures to Eliminate or Reduce Causes and/or Problems. The expansion of agricultural schemes should be restricted by taking measures to conserve the fertility of the soil (i.e., crop rotation and use of fertilizers), rather than continually abandoning barren areas and shifting cultivation. The farmers would remain on the same piece of land indefinitely and would be responsible for sustaining the fertility of the soil. Trees for charcoal production must be obtained from salvage of wood removed for farmed areas. When such areas become scarce, separate fuelwood plantations calculated to meet the demand should be established. Again, methods of converting timber into charcoal must be renovated to cut down on waste. Afforestation projects should be undertaken to compensate for the cleared areas occupied by farms, to protect other resources, i.e., catchment areas, eroded sites, to provide habitat for wildlife, and to provide local needs of timber and cellulose.

Three other management strategies are of importance. Grazing areas should be enriched with fodder plants and grazing controls should be enforced.

This region contains tall grasses which are extremely flammable when dry. Therefore fire lines, fire patrolling and extension against fire hazards are very important corrective measures.

Establishing gum gardens (Acacia senegal), and pole plantations (Acacia seyal) are short term investments which may be attractive to the private sector and should be encouraged locally.

Implementing the Corrective Measures.

The corrective measures presently being undertaken consist of reclaiming abandoned Mechanized Crop Production schemes by planting Acacia senegal, selecting fast growing tree species, and obtaining royalties on charcoal production. The institutions carrying out these corrective measures are the Forests Administration and the Forestry Research Center. What has been done to date is not much compared to the size of the devastated areas. The projects undertaken, however, have been done well.

Constraints to Implementation. The lack of a resource use policy is the main constraint to implementing corrective measures. In the absence of such policy people will use the resource to their own benefit (i.e., shifting mechanized cultivation, timber cutting, charcoal production, grass fires, etc.). One of the problems with the Mechanized Crop Production Schemes is that the farmers are not necessarily from the region. Usually they are rich merchants from Khartoum or other towns. They apply for these scheme holdings and buy licenses to farm. Generally they do not abide by any regulations set by the Mechanized Crop Production Corporation and do not follow any conservation rules. They are absentee farmers represented only by their farm wage labourers. They are unknown to the management of Mechanized Crop Production Corporation. This enables them to continue bad farming practises unregulated. Since the wealthier land owners can buy up other peoples licences, they can be farming every season and committing the same offenses in many areas. While grain farmers may profit in some years and lose money in others, charcoal producers always profit, so their activity is continuous. They are not discouraged by the Forests Department's taxes. In addition charcoal producers are local residents. The lack of finance and staff mentioned in an earlier section also constitute constraints to implementing corrective measures.

The degree of local participation remains low. In this region the local farmers (at least in the Blue Nile Province) would like the forest reserves to be given to them in order that they could increase their farm sizes (El Sheikh 1981). This attitude has been developed and influenced by the methods followed in farming such reserves. The quick return a farmer can get on his crops, the type of management and ownership of the schemes, overcutting and overgrazing do not encourage afforestation in this region.

MIXED DECIDUOUS FIRE-SWEPT FORESTS REGION

This ecological region is centered in southeastern Sudan, in the Bahar El Ghazal and Equatoria Provinces. However, it also stretches into western Kordofan and southern Darfur, and along the Ethiopian frontier from the River Setit to the banks of the Upper Akobo River. The greatest part of this region occurs on laterilic soils. The portion of this region that lies in Kordofan and Darfur occurs on sands while the eastern part of this region has rocky soils and foothills (Figure 4.4).

This ecological region contains some of the most valuable timber tree species in Sudan. These include: Isoberlinia doka, Khaya serogalenas, Daniella oliveri, Afzelia africana, Khaya grandifoliona, Scierocariabirrea, Anogeissus schimperi and Butyrospermum niloticum. It also contains the most promising exotic tree species such as teak (Tectona grandis), Cupresus lusitanica, Peris radians, Cassia siamca, and Cedrella trona. The indigenous flora is rich and the potential for introduction is great in this area of approximately 100,000 square miles.

Causes and Corrective Measures.

Causes. This zone suffers from felling and burning. In Kordofan and Darfur Mechanized Crop Production Schemes are developing in this zone. In Bahr El Ghazal and Equatoria shifting cultivation, fires and felling for sawmills are destroying the ecological region.

Shifting cultivation is the oldest destructive factor in this region. It is gaining in eminence with the increase of population and development of all season roads. The farmers used to shift once the soil lost its fertility, giving the land an opportunity to recover as pioneer species re-established themselves. Such areas in their various stages of succession are locally called "Bobai." They are very common in accessible areas and near large habitations. Now farmers seem to stay until the land has lost all its top soil and becomes bare rock. Such land is becoming very common and is called "Saffia." These areas do no carry any vegetation and foresters synically call them their best fire lines.

Fires rage throughout this region annually, particularly in the dry season (January through May). Termite mounds, Saffai and streams are the only fire breaks. These fires affect stocking, species composition and timber quality.

The Forests Department started to cream this region fifty years ago. Scattered groups of sawmills in Bahr El Ghazal and Equatoria together with hand sawing camps have devastated a great deal of this ecological formation. The rate of replacement is negligible. Also, to transport these selected timbers, roads have been constructed and maintained. They have attracted illicit fellers and farmers who strip whatever cover is left.

Adequacy of Available Information on Problem. The amount of land clearing for shifting cultivation becomes very evident when old air photos are compared with current satellite images. There is no data giving exact figures on the percentage or amount of land cleared.

Again, exploitation for sawmills was selective and scattered as the owners of the sawmills were looking for certain species and sizes of trees. The cleared areas look like a mosaic created by the scatter and local dominance of the required species. The area clear cut can only be inferred from Forest Department Reports. For instance, if the distance from the sawmill to the cutting sites is greater than fifteen kilometers, than one can infer that a radius of fifteen kilometers has been creamed of its valuable millable trees. What is needed is a resource survey or get some data on the standing stock.

Corrective Measures to Eliminate or Reduce Causes and/or Problems. The known corrective measures consist of minimizing shifting cultivation, better planning and more economical use of the resource on the part of existing sawmills, protecting the region from wild fires, and afforestation programmes to replace the trees cut for sawmills.

Implementing the Corrective Measures.

The corrective measures presently being undertaken include a planting programme, a research programme and a fire protection programme for the forests reserves. Institutions carrying out the corrective measures are:

the Forests Department and
the Forestry Research Center.

Plantations of exotic and indigenous tree species have been established. Fire lines were cleared to protect these plantations. The Forestry Research Center has been conducting species trials in the region to select the most suitable tree species for afforestation in the region. The efforts in this region are not enough. This region has suffered interruptions of many programmes because of the seventeen year civil war.

Constraints to Implementation. The major constraints to implementation are lack of a resource use policy, poor management, lack of finance and lack of trained personnel. Presently local participation is not an important factor in reducing deforestation. Perhaps with more extension education the potential for local participation could be tapped.

HILL MASSIFS IN THE ACACIA REGION (#6 Figure 4.1)

This area consists of Jebel Marra Hills in Darfur, the Nuba Mountains in Kordofan and the Ingessana Hills in the Central Region.

This group of hills contains a richer tree flora than their surrounding area (Andrews 1948). They have also suffered more deforestation than the surrounding areas, and because of slope, they also have suffered from severe soil erosion. In the past century both Jebel Marra and the Nuba Mountains had been terraced, rationally farmed and protected from fire. The present day scene of degradation started only about thirty years ago. With advances made in mechanized farming and clearing, large areas are being cleared for horticultural crops.

Causes and Corrective Measures.

Major deforestation is being caused by agriculture, horticulture, fire and timber and fuelwood cutting, in this order of importance. Data is not available at present on the standing stock and species composition of the main tree flora.

Problems. Corrective measures should include terracing, tree planting and fire protection. Tree plantations should be calculated to meet the local demand for timber and fuelwood.

Implementing the Corrective Measures.

The Forests Department and the Forestry Research Center are active in Jebel Marra. Afforestation with exotic tree species such as Cupressus lusticana, Caltitris sp. and Eucalyptus sp.. The Forestry Research Center is also testing more species on various sites in these hills. Nothing has been done in the Nuba Mountains or the Ingessana Hills apart from some trails of Boswellia papyrifera on some slopes of the latter. In general, very little has been done to date.

The constraints to implementation are mainly lack of finance and trained personnel to carry out a proper reforestation programme of tested species. Local residents want these hills for their own uses, i.e., wood cutting and grazing. Their participation in any reclamation programme would be conditioned by allowing adequate areas for local use.

SUMMARY AND CONCLUSIONS

In the desert region, Halwagy (1962) reviewed the literature on the incidence of the biotic factor on vegetation where grazing, fire and human activity led to deforestation. The past discussion showed that in every ecological zone cutting of trees for agriculture, fuelwood and overgrazing has led to deforestation. This has created a national problem where the habitat lacking trees has gradually lost its characteristics and became degraded. Signs of desertification such as high velocity unabated winds, bare soils exposed to wind and water, low crop yields and scarcity in surface water have shown in most of Sudan. The problems from these conditions are manifested by migration of people and animals to parts of the country which are less affected by deforestation. This again puts added pressure on the forest resource of those regions.

The solution of this problem, in each region, rests on formulating a sound resource use policy. Such a policy would treat the deforestation problem as part of an ecosystem where the right species of trees on the proper sites will enhance the ecosystem's sustained productivity. The outcome of implementing such a policy would answer the immediate needs of local populations for food, fodder, fuelwood, timber, shelter, etc. Such an ecosystem would then be in the hands of the real beneficiaries -- the local population. It is known that a productive and soundly managed ecosystem will have excess production to help less productive areas. This proposed integrated resource use policy is in direct contrast to the present resource mining being practised by the Mechanized Crop Production farmers, the creaming (cutting the best trees) of natural forests practised by the Forests Department, the overcutting by charcoal producers, and the general practise of overgrazing.

CHAPTER FIVE

This chapter focuses on the problem of siltation of reservoirs and irrigation systems and its impact on agricultural productivity. The deposition of silt in irrigation canals and the subsequent build-up of aquatic weeds may result in losses to productivity of up to 40 percent. Other costs of siltation include loss of hydro-power potential since methods of silt removal involve measures that lower head and interfere with generator operation.

Most serious, however, is the loss of agricultural production. While silt and weeds can overtake a canal very rapidly, the cleaning of canals is a slow and costly, labor intensive operation. Moreover, efforts directed at canal maintenance drain manpower from the agricultural schemes often at critical periods of the planting, weeding or harvest cycle. Dr. Ali cites the need for increased manpower, mechanization of canal maintenance, and basic research in order to raise the productivity levels of the irrigated schemes.

Reduced Agricultural Productivity in Irrigated Areas with Particular Reference to Silting in Reservoirs, Rivers, and Lakes

OMER EL BADRI ALI

INTRODUCTION

Alluvial deposits of the semi-arid zone, especially in the Sudan, have been of great interest and significance because of their agricultural activities in these areas. For centuries these alluvial areas have been formed and

revitalized through continued sediment deposition from rivers and khors (small seasonal streams) in the Sudan. These lands exhibit considerable variation from small alluvial fans in khor Baraka and El Gash in the Eastern Region (Figure 5.1) to a series of gently sloping alluvial fans (Williams and Adamson, 1976) and flood plains merging together into one large area of alluvial deposits of the Gezira and Managil in central Sudan.

Due to the construction of complex irrigation systems on major rivers, particularly in the Gezira, Khashm el Girba and Rahad schemes, there have been instances where appreciable quantities of silt are deposited in the newly built reservoirs, irrigation canals, and in rivers. This silt, essential for soil fertility and crop production, is not reaching the fields and agricultural lands where it is desperately needed. More significant,the silt deposition has created problems (primarily for irrigation) for agricultural development. The situation clearly leads to difficulties in maintaining water quantity and flow for irrigation. It increases blockages in pumps and pipes. It leads to increased vegetation growth in canals. It contributes to health problems by slowing the flow of water. All of these problems bear directly on difficulties encountered in increasing field yields and total food production.

Regional problems to be considered in detail in this context include:

1. excessive sedimentation in reservoirs reducing their efficiency;
2. deposition in river channels in general, interfering with their flow regime;
3. silting of dam-reservoir with direct impact on the generation of hydroelectric power and indirect effects on pump irrigation;
4. deposition in irrigation canals leading to inefficient irrigation;
5. silt deposition increasing the growth of aquatic weeds which may directly or indirectly affect agricultural productivity.

With the exception of the latter two, which will be treated as one problem, all the other problems involve different magnitude, causes, and corrective measures. Each will be considered separately.

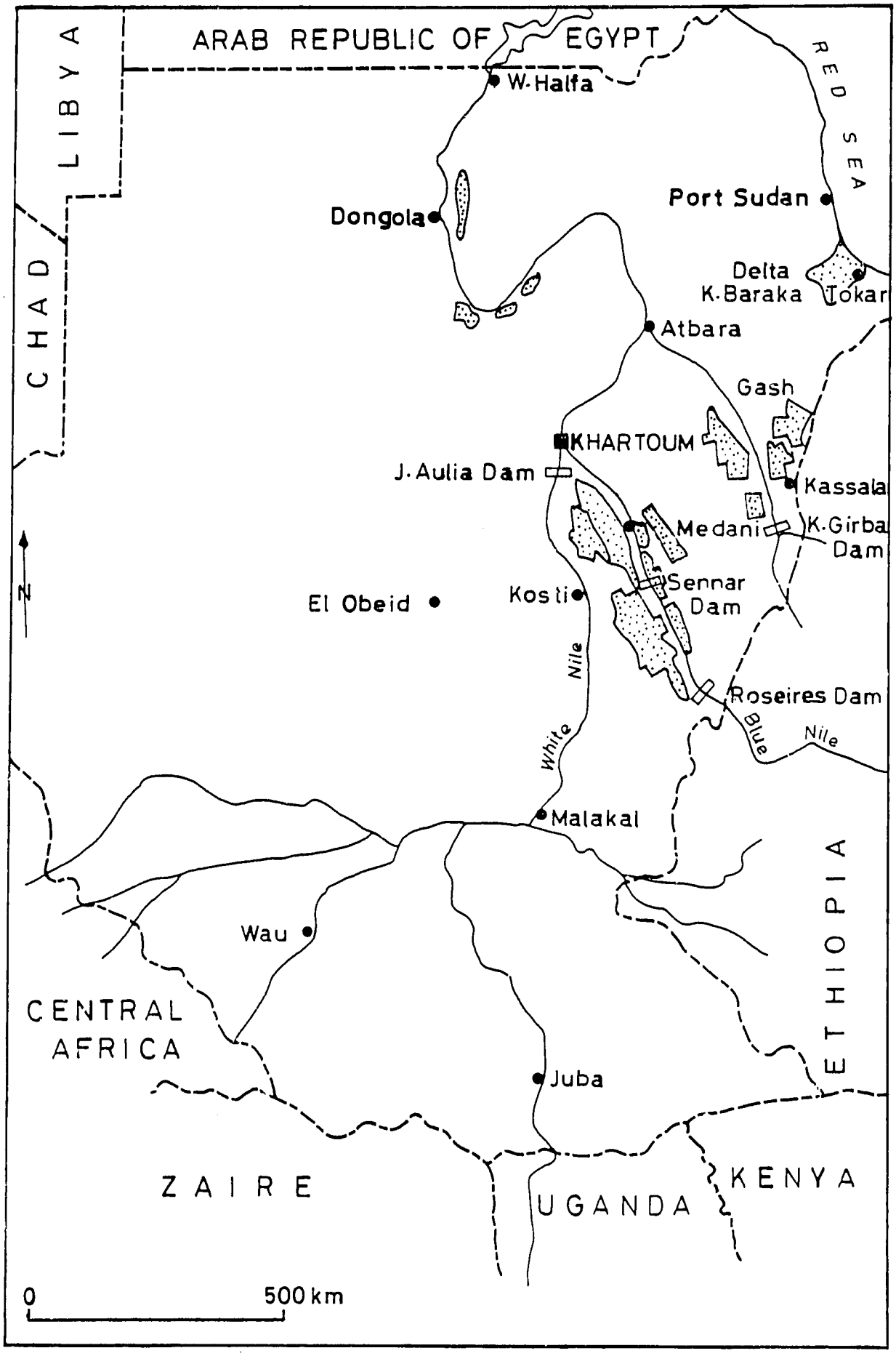
SILTING IN RESERVOIRS: CAUSES AND CORRECTIVE MEASURES

Magnitude and Rate of Change

Three reservoirs in the Sudan are significantly affected by this problem: Roseires and Sennar reservoirs on the Blue Nile and Khashm el Girba Dam on the Atbara River (Figure 5.1). Together these reservoirs provide the bulk of the water requirement for gravity irrigation in the major schemes such as the Gezira and Managil, Khashm el Girba and Rahad. But it is apparent that silt has influenced the originally designed capacity and operation of these dam-reservoirs and associated irrigation canals. For example, the Khashm el Girba storage reservoir was designed for a total volume of 1300 X 10^6 m^3 in 1976.

FIGURE 5.1

MAJOR IRRIGATED SCHEMES



Source: Water Resourses of Sudan

Existing & Probable Projects Irrigated

The volume had reduced to 660 x 10^6 in 1982; by 1997 the volume is expected to fall to 500 X $10^6 m^3$ (Annex 9, New Halfa Rehabilitation Project, 1980).

Generally, siltation of the existing reservoirs is taking place at an average rate of 50 million m^3/yr or 90 million tons/yr of silt load (although it will prove lower on the Blue Nile than the Atbara). Even the Rahad barrage, although with negligible storage capacity, will soon face difficulties due to siltation. The life span of the dam-reservoir is reduced accordingly and already those of Khashm el Girba and Sennar have an actual life span of thirty years (World Bank Report, 1979).

The magnitude of the problem is particularly great at Roseires and Khashm el Girba. Both the dead storage as well as the live storage of the two dams are filled up with silt. This means that the regulated run-off available for irrigation is reduced. A large island or sand bar has already built up less than 1 km upstream of the Roseires dam; no sign of such an island had been noticed up to 1970.

It is also worth noting that the volume of Roseires water at level 480 m.a.s.l. in 1966 was 3.024 milliards; that of 1981 at the same level was only 2.350 milliards. The discrepency, attributable to silting, will ultimately reflect on the agricultural development in the country. The loss of 0.674 milliards of irrigation water would roughly mean a virtual loss of about 40 percent of potential food and cash crops produced annually by such as large a scheme as New Halfa Scheme (the actual water allocation to the New Halfa Scheme in the Nile Agreement is 1,622 x 10^6 m^3 per year).

Principal Causes and Relative Importance

Both the Blue Nile and the Atbara Rivers are characterized by seasonal fluctuations in their hydrological regimes and are both known for their heavy load of suspended matter and bed load transported from the Ethiopian highlands mainly during the flood season from July to October. Concentration of suspended matter in the Blue Nile, Atbara and White Nile is given in Table 5.1 and the actual change in concentration in the Blue Nile over particular flood seasons is shown in Figures 5.2, 5.3, and 5.4.

The sudden check to the water velocity by the dam walls is the principal cause of silt deposition. As water turbulence declines, its holding capacity for suspended particles lessens. Clay, silt, and fine sand particles will sink and settle.

Ali (1972) found that the total amount of suspended matter transported by the Blue Nile past Sennar Town was in the range of 80 to 100 million tons/yr during 1959 and 1961 flood seasons (as calculated from analysis by the Ministry of Irrigation). They amounted to less than 70 million tons/yr in 1967 and 1969. That drop is attributed directly to deposition associated with the construction of the Roseires dam in 1965.

TABLE 5.1

NILE WATERS SILT LOAD DURING FLOOD PERIOD

	Main Nile	Atbara	Blue Nile	White Nile
Load (million tons/year)	110	80	140	14
Volume (million m^3/year)	60	45	75	7.5
Suspended Matter	5,400	8,000	7,000	1,500
Average Suspended Matter	1,600	6,000	5,000	850

SOURCE: World Bank 1979.

Adequacy of Available Information

Information presently available on the problem is rather on the theoretical side. Specific, quantitative data are inadequate. The work referred to earlier is of limited extent being concerned only with the situation at Khartoum during flood seasons 1967-1969 and Sennar during the 1959-1961 flood seasons.

Records of silt concentration in rivers are sporadic. Apparently nothing is published on the Atbara. Those data which are available for the Blue Nile are provided by the Ministry of Irrigation at discontinuous intervals. They are obtained with traditional sampling methods which are not always accurate. The only quantitative study is said to have started in 1981 on the Roseires silting problem but data are not yet available. More advanced techniques, including modern survey boats and electronic measurement devices, must be employed. A continuous record of the quantity and rate of silting is required.

Also there is practically no information on the relationship between the quantity of silt in suspension in irrigation water and the crop yields; nor are there data on relationships between the silt deposition in dams in specific season and agricultural productivity. Research pertaining to both of these issues is urgently needed.

Specification of Corrective Measures

Corrective measures to minimize these problems may include draining of the bulk of the flood water through dam sluices. Local stirring of the mud by mechanical means will help to flush accumulated silt from upstream walls.

It is also possible to build concrete walls or smaller dams in the upstream reaches of the Blue Nile and River Atbara to act as velocity breakers and silt traps. A large amount of bed load and suspended load will be deposited before reaching the dam-reservoir area. In order to prolong the life span of the Khasm el Girba dam, the government is planning to construct the Burdana dam (on the Settite River) which would be used essentially as a silt trap.

Along with the silt, huge logs and debris have to be removed. These tend to enhance further silt accumulation by acting as a binder for mud deposited behind the dams. The bulk of these logs and debris originate from catchment areas along the Ethiopian-Sudanese border; local bank erosion also contributes some logs.

No corrective measures are known to reduce concentrations of suspended matter in flood waters or to eliminate silting problems.

FIGURE 5.2

MEAN CURRENT VELOCITY AND CONCENTRATION OF SUSPENDED MATTER IN THE BLUE NILE AT KHARTOUM

FLOOD SEASON 1967

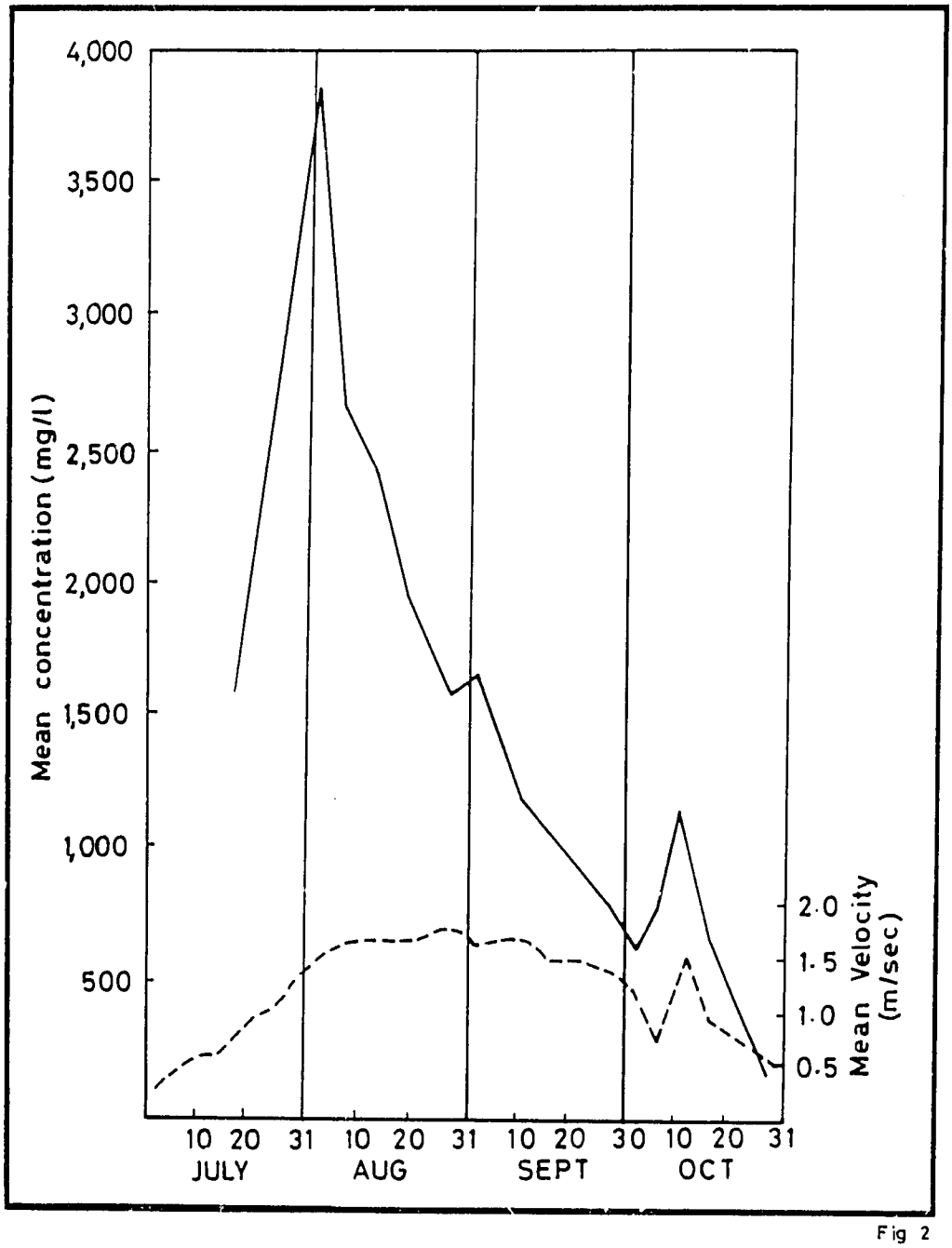


Fig 2

FIGURE 5.3

MEAN CURRENT VELOCITY AND CONCENTRATION OF SUSPENDED MATTER IN THE BLUE NILE AT KHARTOUM

FLOOD SEASON 1968

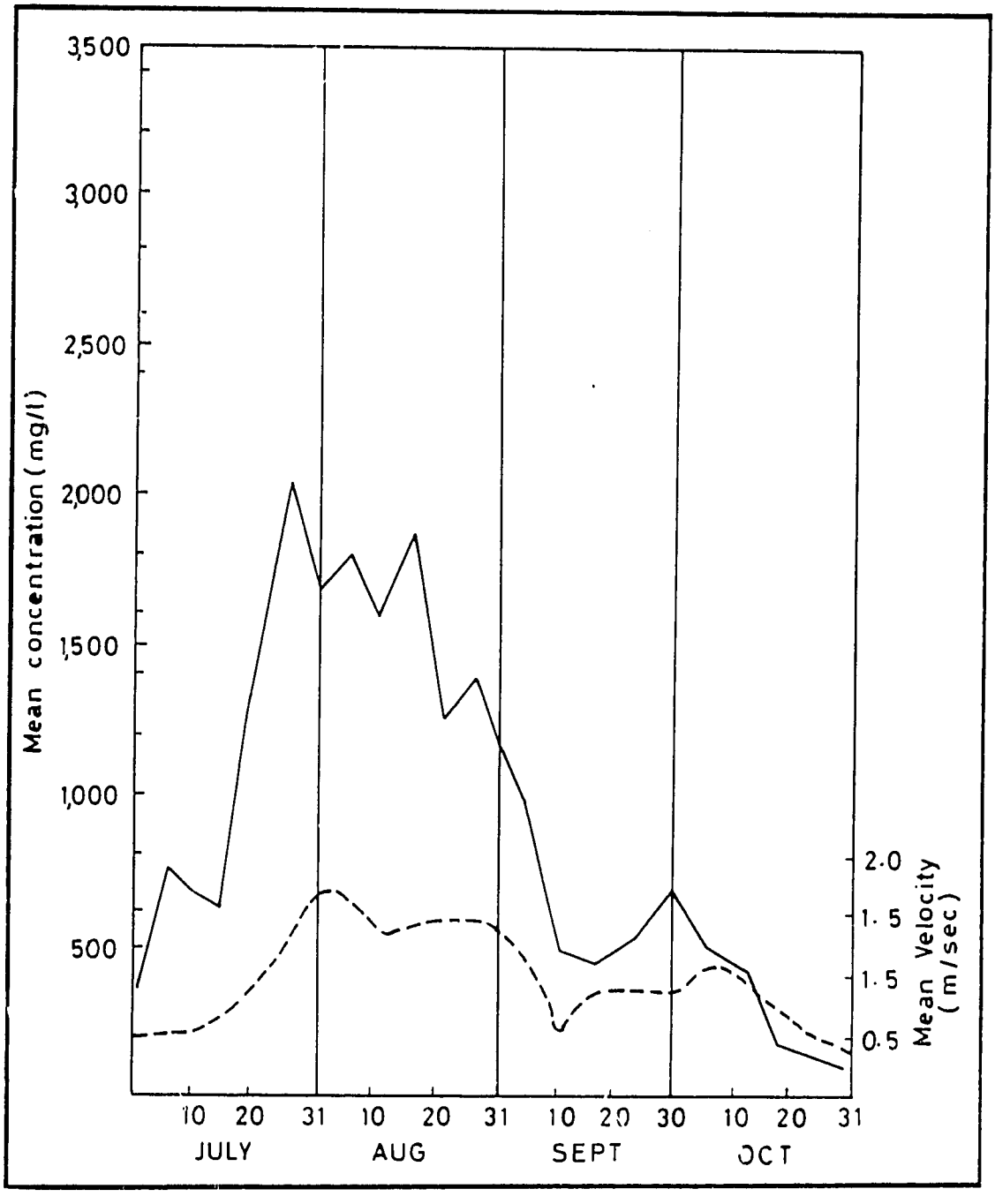
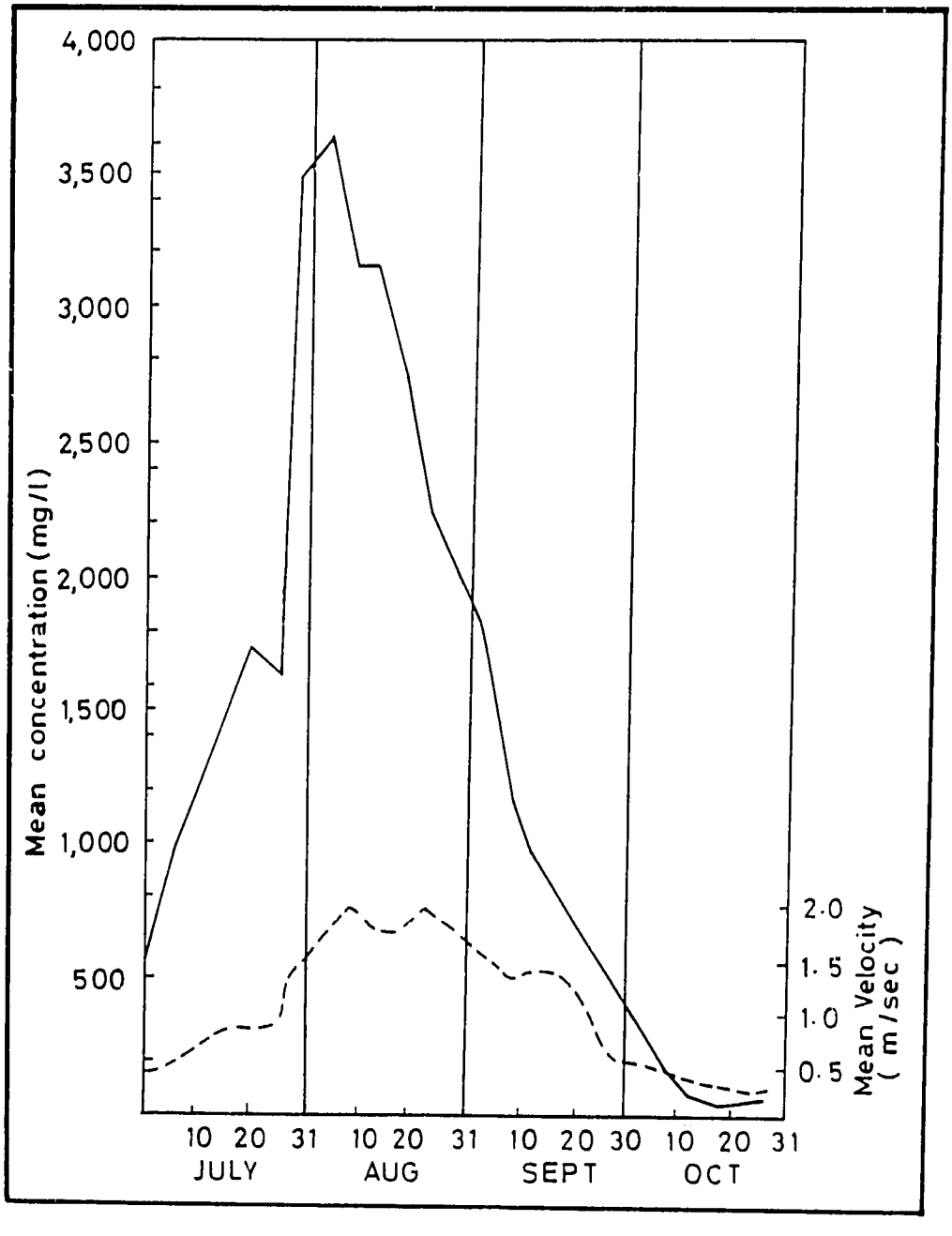


FIGURE 5.4

MEAN CURRENT VELOCITY AND CONCENTRATION OF SUSPENDED MATTER IN THE BLUE NILE AT KHARTOUM

FLOOD SEASON 1969



Implementation of Corrective Measures

A number of corrective measures are currently being undertaken:

Flushing the dam during the flood period by holding a high level of water and suddenly allowing it through the sluices creates considerable flushing turbulence. This method is applied only at the Khasm el Girba dam where flushing may take up to ten days. It is not employed at Roseires or Sennar because it interferes with hydroelectric power generation which cannot be interrupted. It may also cause damage in the generator turbines if wood blocks pass through the sluices. At Roseires they also tend to allow the maximum possible amount of flood water to pass, keeping the optimum for power generation. It has been reported (World Bank, 1979) that if flushing operations are carried out regularly at the beginning of the filling of the reservoir during the flood season, the rate of siltation is likely to be only 10 to 25 million m^3/year. Also a resident engineer, technical staff, and labourers are based at each site. With the facilities they have, their effort is appreciable though not enough.

In spite of these measures, there continue to be problems. First, there is a lack of trained staff, equipment and finance. Second, no statutory or constitutional constraints to implementing corrective measures exist, except at Roseires where it is government policy not to interrupt the power generation because the country is almost wholly dependent on hydroelectricity.

Lastly, it is worth mentioning in this section that any attempt to restore the reservoir volume lost by siltation such as dredging or flushing, are normally uneconomic and ineffective.

DEPOSITION IN RIVERS

Causes and Corrective Measures

Associated with reservoir siltation is the deposition of sediment load in river channels. This is an especially severe problem in the Blue Nile, River Nile and Atbara River. Smaller channels like Khor Baraka, and Khor el Gash also suffer from this phenomenon. The process leads to continued migration of major streams within the flood plain, shifting from established fields including fruit farms in the Northern Region, and escaping from concrete-built sites of existing irrigation pumps. Bank erosion associated with these processes, locally known as "el Haddam," had once been announced by the Ministry of Irrigation of the Northern Region as a severe problem affecting the future agricultural and economic development in the region.

The situation is sometimes worse in the delta of Khor Baraka (Figure 5.1) where people depend solely on the annual flood water. This water so often makes its way through a new channel down to the sea, leaving behind great

fertile soil without irrigation and escaping all expensive effort of control by the government and locals. On some occasions only about 25 percent of the land may be covered by the flood. Similar incidents are reported in Khor el Gash which has a similar hydrological regime.

The magnitude of the problem is apparently great, especially if we consider the small area available for agriculture in areas such as the Northern Region and parts of the Blue Nile upstream reaches. The rate at which change is taking place is difficult to assess.

Obviously the reasons for such changes are related to river systems though there is a tendency to attribute the problem to the reservoir silting discussed earlier. For example, Kotb and Abd el Mottaleb (1981) suggested that the degradation effect in land and banking downstream from the Aswan High Dam is due to "clear" water flowing downstream from the dam. They have illustrated the scouring phenomenon in reaches downstream from the High Aswan Dam, using detailed series of cross-section changes in mean depth and grain size of bed material.

Natural causes interfering with stream behavior and leading to erosion/deposition problems are noticeable in the Khor Baraka delta. These tremendous wind actions (Haboub) blow huge piles of sediment in and out of the pre- existing channels just before and during the flood period. This is a highly uncontrollable factor pertaining to the problem.

Adequacy of Data Available

The data in this field are again inadequate. All that exist are incomplete records of concentration of suspended sediment in rivers like the Blue Nile and Atbara. A local case study by Eng. Ibrahim Banaga of the Ministry of Irrigation (Khartoum) in 1980 may be quoted as an example of a major silting problem from the Northern Region. Sediment accumulation in Khor Habrab near Dongola (Figure 5.1) caused such a serious shortage of water that people who needed water to irrigate wheat, beans, etc. almost deserted their fields and villages. The amount of silt is tremendous, reaching up to 5 meters in thickness. A total of 3,000 tons must be removed before any water can pass through to the scheme. To verify the scope and intensity of the existing problem, further research is needed to help devise plans to eliminate or at least reduce the extent of the problem.

Corrective Measures

Known corrective measures include construction of concrete embankments to prevent erosion and soil shifting. Dredging is almost impossible in a flowing river channel unless followed by construction of controlled gate systems in the smaller feeder streams. Suggested corrective measures for the Habrab problem included manual dredging, building of localized concrete basement and construction of side and central control gates. A cost of £S 150,000 was too much for the regional government at that time. Certainly the cost would be almost double that sum today, allowing for inflation. The wind effect in the delta of

Khor Baraka could partially be controlled by planting a green belt of suitable drought-resistant trees. However, considering the earlier problem of bank erosion, these wind breaks must be located some distance from the stream edges. Otherwise no corrective measures could be undertaken to control the vigorous flood nature of that khor.

Some of the corrective measures mentioned above are presently used. For example:

1. Limited work on embankments is undertaken on major rivers;

2. The government and peasants cooperate in delta Tokar (Baraka) in building a series of sand/rock dams upstream to help in diverting the water and breaking the velocity of the khor;

3. A green belt system is being introduced though mainly to protect Tokar town and the nearby farms in the Baraka delta.

However, what is being done is very small and major difficulties in obtaining finance and suitable machinery are hindering these efforts. Local people readily help in employing suitable corrective measures.

HYDROELECTRIC POWER

Causes and Corrective Measures

Hydroelectric loss is a national problem seasonally affecting the country and is again intimately related to silting in dam-reservoirs where the main power of the Sudan is being generated. It also pertains to competition with irrigation activities over the water available and has a direct effect on agricultural productivity when water stress is exerted on crop plants irrigated by electrical pumps because of frequent power cuts. Silt accumulation in front of the turbine area reduces the headwater level and is occasionally accompanied by debris from wood logs which often block the screen equipment. Competition with irrigation schemes for water is also a problem to which silting contributes by reducing the total volume of water available to either.

Measures presently employed are:

1. A protective barrage artificially built by connected floating barrels for the protection of the turbines.

2. Manual clearance of wood blockages.

3. Keeping the reservoir at the lowest possible level during river flood season in order to minimize the silting effect and also at an appropriate level to allow for the removal of driftwood. At Khashm el Girba, for example, a reference level of 468.5 metres is actually 1.5 meters above the full supply level of the main canal. This level is required for driftwood spilling before flushing.

No constraints to complementing corrective measures exist but sediment flushing operations may endanger the electrical installations if not properly timed with driftwood spilling. Reaching the optimum water level to generate power generally offsets measures to minimize siltation in the reservoirs, especially at the Sennar and Roseires dam sites. Consequently, the corrective measures are inherently problematic and chronically insufficient although the staff of the Ministry of Irrigation, who employ these measures, seem to be doing their best to compromise. They are presently in need of both financial and technical help to overcome some of the difficulties.

SILTING AND WEEDS IN CANALS

Silting and weed infestation in irrigation canals are serious interrelated problems which are magnified by the recent intensification of cropping and rapid conversion of vast areas into intensive agricultural production in the Sudan. Excessive seepage and evaporation occur in irrigated areas and canals silt up rapidly. When flow is also retarded by weeds, yield is further reduced. Irrigated schemes cannot be supplied with water on schedule when weeds and silt infest and clog canals.

Causes and Corrective Measures

The Gezira irrigation is by gravitational flow through canal systems from Sennar dam. The main canal receives water from the Blue Nile. Major canal branches off from the main canal carry water supply to minor canals. The minor canals feed outlet channels which ultimately irrigate the crop land. The rate of water flow in these canals is very slow providing ideal conditions for the growth of weeds and silt deposition. Clearing of the canal system in the major irrigation schemes of silt and associated perennial and annual aquatic weeds is extremely expensive and energy consuming. The problem causes serious reductions in yield creating severe labour shortages at critical periods on the large agricultural schemes (Hamdoun and El Tigani, 1977).

There is, however, no estimate of the total loss caused by silting of canals or by weeds in the Sudan. In the U.S.A., it is estimated that 5 to 15 percent of all food and fiber production is lost because of weeds (Chandler, 1974). This amounts to a total waste of $5 billion annually for the U.S.A. alone. In the Sudan the relative losses would probably be greater.

One of the main factors contributing to the deterioration of the productivity in the Gezira in the last few years is the inadequate supply of water associated with silting and weed infestation in the network of canals. The situation is growing worse as a result of the increased intensification of cropping. Water weeds, of which 23 species were recorded in the Gezira Scheme, are retarding water flow, enhancing sediment deposition and hampering irrigation (Hamdoun and El Tigani, 1977). These weeds together with perennial land species infesting the fields cause severe crop losses if weeding is neglected or delayed. Unweeded cotton, sorghum and groundnuts give 60 to 90 percent lower yields than a clean weeded crop (Idris, 1970; Thomas, 1970; Hamdoun,

1971). The situation is even more serious in the Khashm el Girba Scheme. Some heavily infested areas have been abandoned and appreciable areas of cotton crop was disced in the 1969-1970 season to control annual weeds because hand weeding was considered expensive and practically impossible.

Adequacy of Available Information

So far there is very little research on any particular aspect of the canal silting and weed problem. Available data are inadequate. A recent project to study the silt/weed problem in canals started late in 1981 as a joint project between the Ministry of Irrigation and the Blue Nile Health Project of the Gezira. Hopefully, data will soon be available on the scope of the problem and measures of control.

Corrective Measures

Measures so far employed include manual hoeing of the small outlet canals by individual efforts and large scale clearance of canals is practiced annually in the Gezira by the Ministry of Irrigation. The use of various types of dredgers is a common practice. Further efforts and more machinery are needed as well as a greater financial commitment.

Implementation of Measures

Weed control and silt dredging go together. Chemical control of the aquatic weeds is being introduced despite fears of pollution and environmental hazards. Weeds in irrigated schemes are difficult to eradicate because of their rapid and varying propagation methods. The control of weeds and clearance of canals is the responsibility of the Ministry of Irrigation. A large staff is involved on a permanent basis, but sometimes extra temporary staff (labourers) are employed.

SUMMARY AND CONCLUSIONS

Silt deposition from the suspended bed load of rivers and streams into reservoirs, river channels and irrigation canals has created serious regional problems to agricultural development by reducing agricultural productivity in the Sudanese irrigated land and wasting part of the national income. Reduction of the storage capacity and life span of existing reservoirs, difficulties in hydroelectric power generation, water stress on crop plants due to retardation of flow in irrigation canal and weed infestation are some of the most outstanding effects of the problem. The corrective measures presently employed to control these problems are significant and appreciable, but nonetheless insufficient. Greater effort is needed in conducting field research, giving technical training at various problem sites and providing government financial support.

CHAPTER SIX

Chapter six examines the problem of soil degradation in rainfed mechanized farming. Two basic types of such farms are identified: planned and authorized; and unplanned, unauthorized. All of the farms are required by law to practice soil and flora conservation practices, particularly crop rotation. However, there is no means of enforcing those laws and, as a result, the laws are largely ignored. Consequently, soils are rapidly depleted of nutrients and abandoned. The fields are ofter abandoned in such poor shape that recovery may be nearly impossible contributing to Sudan's already serious desertification problem.

Dr. Homoudi calls for greater cooperation between research centers, the Soil Conservation Department, the Range Management Department, the Forestry Department, and the Mechanized Farm Corporation. It is noted, however, that each of the institutions has its own perspectives, mandate, political base, and time frame, and that cooperation between them will require special energy and attention. Further, research into the problem is sorely needed.

Soil Degradation Resulting from Mechanized Agriculture in Rainfed Areas

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INTRODUCTION

Rain-fed mechanized agriculture developed on an area of not less than 7 million feddans,[1] on the central clay plains of the Sudan. The central clay plains possess extensive good soils and sufficient rainfall ranging between 500 mm and 800 mm. Lack of adequate supplies of sorghum from both the traditional and the irrigated agricultural sectors, availability of large unutilized cultivable land estimated as a potential of 90 million feddans, the low cost of agricultural inputs on rain cultivation compared to irrigated cultivation as

well as the quick returns and comparatively easy implementation, have all attracted planned and unauthorized development of mechanized farming.

For both types of development, soil analysis is done by the headquarters of the Agricultural Research Stations at Wad Medani, and Kadugli in S. Kordofan Province.[2] The problem is that regardless of whether the development is authorized or not, vegetation is cleared and no shelter belts are provided. Rotations are not strictly followed and no inputs, such fertilizers, are added to preserve the soils. Most of the private investors are not closely attached to the land. They are always after quick returns. Most of the farms are run by agents who are either ignorant of resource conservation methods or not concerned either with the short-term or long-term profits as long as they are paid by the farm owners. As a result, there is a complete absence of conservational attitudes among farmers.

All the above factors "have led to widespread soil degradation and erosion. Many dry farming schemes have been abandoned because of weed infestation and poor productivities".[3] A recent analysis of mechanized farming in the Simsim area (developed in 1969) of the Gedaref district proved the fact that floods, together with other problems, caused the abandonment of some farms in the area (Table 6.1). "It is believed that mechanized farming in the Simsim project has disturbed the natural soil water balance in the ploughed layer, resulting in an increase in the soil water surplus, which caused accelerated runoff."[4]

The six provinces of Kassala, Blue Nile, White Nile, Southern Kordofan, Southern Darfur and Upper Nile all have rain-fed mechanized farming. In all provinces the activity is rapidly expanding southwards in search of more humid areas.

RECENT TRENDS AND PROJECTIONS OF FUTURE

Rain-fed mechanized farming is a fairly recent activity. It started during World War II at El Ghadambaliya area west of the El Gedaref (Figure 6.1) to produce sorghum for the troops fighting in Ethiopia and Eritrea. The Gedaref area expanded to reach 1.6 million feddans within the planned area and an additional 1.5 million feddans in unplanned, unauthorized areas. The largest expansion for the rain-fed mechanized sector was planned for in the amended Five Year Development Plan (1971-77). By the end of the plan, 2.8 million feddans were developed in all the mechanized farming areas of eastern central and Western Sudan.[5] In 1976 the 3.3 million feddans under crops, which made 66 percent of the total area under rain-fed mechanized farming, produced 50 percent of the sorghum and 40 percent of the sesame of the national total in that year. Now, (1982) the area reaches about 7 million feddans (Table 6.2).

TYPES OF INVESTMENT ENGAGED IN MECHANIZED FARMING

One needs to look at the different types of investors engaged in rain-fed mechanized farming as this has bearing on resource management, conservation and provision of services and infrastructure.

TABLE 6.1

Deserted Farms in Simsim Project

	73/74	74/75	75/76	76/77	77/78	78/79	79/80
No. of allotted farms	---	89	89	89	89	89	89
No. of cultivated farms	12	12	5	13	33	33	13
% of cultivated farms	---	13.5	5.6	14.6	37.1	37.1	14.6

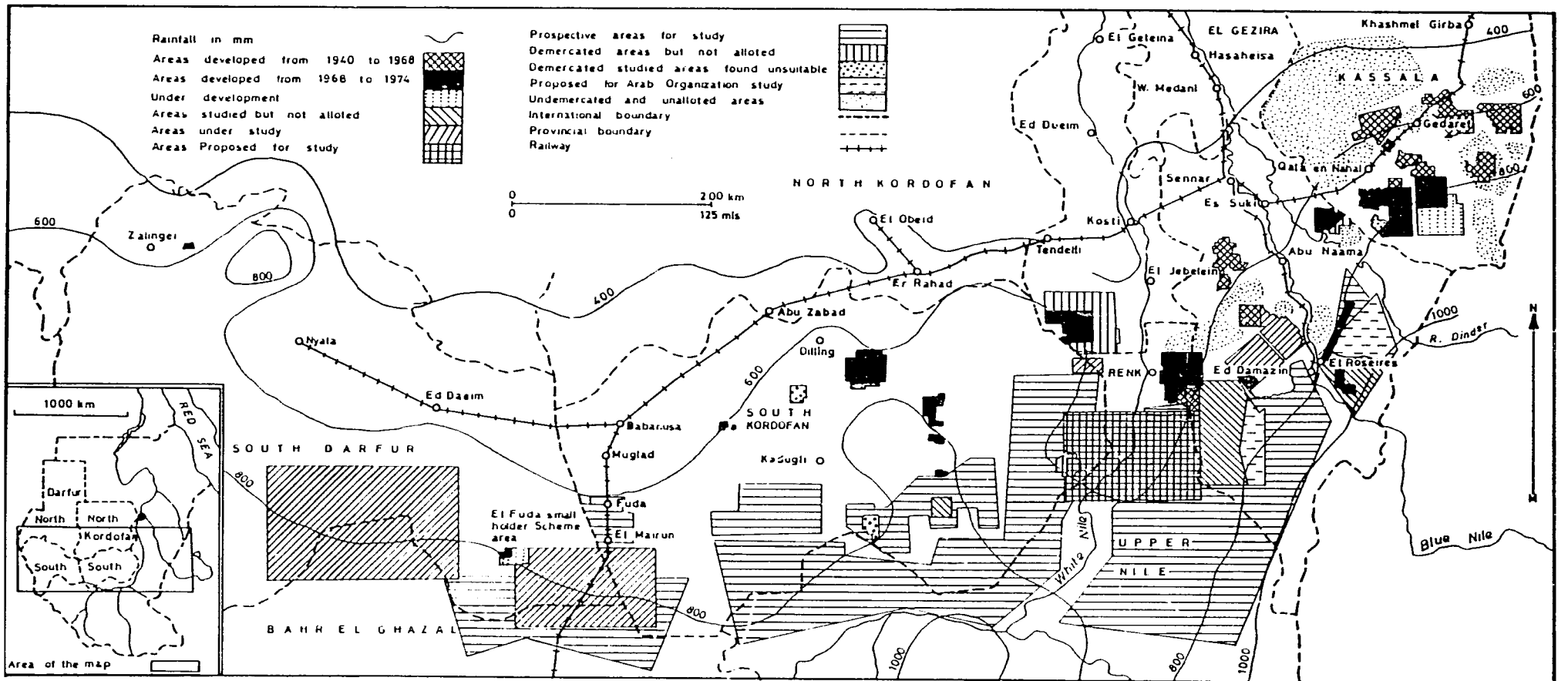
Source: Mustafa El Sayed El Khalil, "The Impact of Mechanized farming on the soil-water Balance of Simsim Project". M.Sc. dissertation, Institute of Environmental Studies, University of Khartoum, 1981, p. 69.

TABLE 6.2

Areas of Mechanized Farming in Million Feddans (1982)

PROVINCE	AREA	PLANNED PRIVATE AND DIRECTED	UNAUTHORIZED
Kassala	Gedaref	1.6	1.5
Blue Nile	Damazin	1.1	1.2
S. Kordofan	Dilling	0.5	0.2
Upper Nile	Renk	0.5	0.4
TOTAL		3.7	3.3
GRAND TOTAL		7 million fed.	

Sudan Rain-fed Mechanized Agricultural Areas



Source M.F.C. Agricultural Statistics Bulletin No.2 1979, Khartoum.

FIGURE 6.1

For this purpose, two main types of investment are identified: 1) Planned authorized rain-fed farming; and 2) Unplanned, unauthorized, (known as undemarcated areas), private rain-fed farming. The first main type includes four sub-types.

The first sub-type includes private planned farms, some of which were opened in the 1940s. These were first run by the government but then offered to the private sector. They came under the supervision of the Mechanized Farming corporation after it was established in 1968. While the choice of the areas, planning, feasibility studies, soil surveys and water and roads provision are all done by MRC, implementation and provision of capital machinery and labour are carried by private investors who lease the land for 25 years. Lease holders pay a low rent of 10 pt/feddan each year. The rent is going to be raised to £Sd 1/Feddan/Year for the season 1982/83. Leases are renewable at the end of the 25 years.

The second sub-type is the private directed sector. This lies under planned development, but is sponsored by the World Bank through the Government. This system was carried into two phases. Phase I developed in 1968 and Phase II in 1973. The two phases cover the areas of Sienat and Simsim in the Eastern Region and Habila in Southern Kordofan Province (Figure 6.1). Under this sub-type the Government provides the same services as provided for the previous group. Farmers are leased plots of 1000 or 1500 feddans for 25 years. They are provided with loans from the World Bank to clear the land. The lease should be repaid during a period of 15 years. Loans are also advanced for the purchase of machinery but should be paid back during the first five years of the lease.

A third phase of the World Bank project is now under implementation. This provides US$16 million to be spent on reform programmes and long and medium term solutions for the M.F.C.'s inability to raise its productivity and gain profits.

The third sub-type includes the planned areas offered for large and small companies, foreign as well as national, under the Agricultural Investment Concessions Act. For this purpose an area of about 2 million feddans in Southern Blue Nile Province is alloted. Only a part of the area is developed at present.

State farms are the fourth sub-type of the planned rain-fed mechanized farms. In 1970 four state farms were established in 4 areas (Table 6.3).

Objectives behind the establishment of the state farms include:

1. To provide experimentation, innovation and practical application of the research results and the demonstration of these for other farmers.

2. To provide training of skilled cultivators and technical workers for both farming and machinery repair.

TABLE 6.3

Distribution and Areas of State Farms

PROVINCE	REGION	AREA
S. Kordofan	Agads	200,000 Fd.
Kassala	Simsim	70,000
S. Kordofan	Habila	30,000
S. Darfur	Nyrtitti	30,000
TOTAL		330,000

Source: Managing Director's Report of 1982.

3. To produce a surplus to be stored to stabilize prices of basic food crops.

4. To produce a surplus for export in the hope of getting hard currency to support the government treasury.

Unfortunately, for the last five years state farms suffered from many problems and few of these goals were realized. These problems include: a) lack of both fixed and current capital, fuel, machinery spare parts and skilled labour; and b) competition for skilled labour from the private sector which offers better salaries and wages. These problems have led to low production compared to that of the private farms. Production did not contribute to exports but all output is marketed to the Agricultural Bank to supply some Governmental Departments (e.g., The Prisons Department), to areas of deficit, and for refugee settlement camps. Some of the production is stored to stabilize prices.

Nonetheless, state farms fulfil two other aims. First, they continue to follow the recommended three course crop rotation of the cultivation of sorghum followed by sesame or cotton and a third year of fallow. This rotation is considered to be useful for soil conservation. State farms also continue in the production of cotton to supply the local textile factories with some of their needs for short staple cotton. Private farms stopped cotton cultivation completely. Second, state farms have also succeeded in providing training for workers in technical as well as agricultural skills. However, trained workers leave to work on the private farms as soon as they find opportunities for better payment.

It is now recommended by the World Bank, in the phase III project, that state farms should be transferred to private farms or private companies. The Government is now in the process of sharing Agadi state farm in Southern Kordofan Province with the Arab Authority for Agricultural Investment and Development. Ten thousand feddans of Simsim state farms are shared between the Sudanese and the Canadian project for rain cultivation production. The four state farms cultivated cotton, sorghum, and sesame (Table 6.4).

TABLE 6.4

Crops and Areas Cultivated in the State Farms in 1981/82

REGION	COTTON	SORGHUM	SESAME	TOTAL
Agadi	25,000	35,000	2,000	62,000
Simsim	5,000	10,000	----	15,000
Gozroum	----	10,000	3,000	13,000
Habila	----	11,000	----	11,000
TOTAL	30,000	66,000	5,000	101,000

Source: Managing Director's MFC Report of September 1982

Demonstration and adaptive trials for research results for which the state farms were originally established, are going to be transferred to the directed farms which are sponsored by the World Bank. The World Bank is now planning for the promotion and rehabilitation of the whole sector under its phase III project. It is catering for the development of both large and small scale rain-fed mechanized farming.

The second main type of investment is the unauthorized private development of rain-fed mechanized farming. This includes areas opened and cultivated by private investors outside the planned areas and without leases. It is clear that these areas lack planning and considerations for even the minimum soil conservation methods and wise resource management. Expansion has taken place at the expense of forest areas, nomads, and traditional cultivators rights on the land. This leads to conflicts between the different interested groups. Mechanized farms are also in violation of most of the MFC regulations regarding recommended rotation, preservation of shelter belts, and the provision of water sources and roads to serve the labourers and populations. The area under this type of development is estimated at 3.3 million feddans. Little information about this type is available regarding the number of farmers involved.

PRINCIPAL CAUSES OF THE PROBLEM AND THEIR RELATIVE IMPORTANCE

The above details survey for the mechanized farming activity reveals several causes contributing to the problem of soil degradation and infestation by harmful weeds. Sorghum is the dominant crop cultivated in the mechanized farming areas. It covered an average of 89 percent of the area cultivated for the two seasons of 1980/81 and 1981/82. Sesame covered 10 percent of the area and cotton only 1 percent. Sorghum is very exhausting to the soil fertility, especially when continuously cultivated on the same land. Experiments on rotation, carried at Tozi research station from 1959 until 1964 and transferred to Abu Na'ama station in 1965 and continuing up to now, have proven that sorghum is the worst precursor to all other crops as it reduces their production.[6]

Continuous cultivation of sorghum on the same land also results in the spread of harmful hard weeds such as Striga hemira, Abu Mrwa and El Boose.[7] These weeds are difficult to remove, their infestation persists for a long time unless the soil is abandoned for a long period. Some of them, e.g., Striga, grow as a parasite depending upon the sorghum roots for their nutrients. The presence of these weeds either decreases sorghum productivity or, in severe conditions, prevents the growth of the crop altogether. Of the very important causes for degradation in the rain-fed mechanized farming areas is the fact that private farmers do not follow the recommended rotation schedules nor do they allow fields to lie fallow. The recommended rotation is noted below:

FOR 1500 FED. FARMS	FOR 1000 FED. FARMS	ARRANGEMENT
750	500	First year with sorghum
250	250	Second year with sesame or cotton
500	250	Left fallow

The complete removal of the vegetational cover for thousands of feddans is another serious cause of soil degradation. Some forests and shelter belts were first preserved, planned for, and cultivated by the mechanized farming authorities when the first areas were designed. For example, at the beginning of Simsim Project, land cleared for cultivation was 136,136 feddans. Area of natural forest preserved was 36,176 feddans. Orders and regulations state that at least 5 percent of every 952 feddans should be left as forest. Unfortunately, this order is not followed because of lack of enforcement. Now, the scarcity of wood for building and fire-wood for household use is clearly felt by the inhabitants of the area. Forests are continuously receding to the south.

A controversial soil degradation problem is soil compaction versus soil loosening. Some Sudanese scientists[8] advocate the idea that continuous use of heavy machinery or ploughing the soil at the same depth leads to the formation of a hard compact layer under the top soil. This hard layer reduces the soil capacity for water retention and prevents water penetration into the heavy clay soils. This decreases the possibility for the plants to make use of the seasonally available rain water and accelerates runoff. The process is hastened by the complete removal of the vegetation cover. Other scientists counter that the nature of the heavy clay soils of the Sudan and their hardness when they dry up prevents them from compaction. What is feared by some scholars in the areas of mechanized farming, is the loosening of the top soil as a result of the complete removal of the vegetation cover followed by soil loss deterioration due to the exposure and dry conditions of the 6 month long summer. In this case soil moisture loss is definite. Wind erosion is a remote possibility, but water erosion is likely over extensive bare soil tops especially near water courses. This was evidenced at the Simsim area of Kassala Province.[9]

There is an argument that mechanization of rain-land in itself is harmless to the soil if proper soil conservation methods are followed, e.g., proper rotation, planting of wind shelters, preservation of forests or part of the

vegetational cover, avoidance of unnecessary machine use regardless of differences in contours and especially near drainage systems to minimize gulley erosion. Mohmoud thinks that some of the negative impacts of mechanization can be avoided if the farmers are convinced to plough early when a minimum rainfall of 100 mm is obtained. It may also be useful to plough in the crop residue which breaks down in the soil to increase its humus content.

ADEQUACY OF AVAILABLE INFORMATION ON THE PROBLEM

It is obvious that more definite results and specific research is needed in this area to clearly identify the nature, types, and magnitude of soil degradation resulting from rain-fed mechanized farming. Research done by MFC to investigate the degree and magnitude of soil fertility degradation at the Ghadambalia area (the first area developed in the mid 1940s) revealed that neither the chemical constituents nor the nutrient content of these soils have changed. However, the soil structure has changed. A hard pan has been formed a few inches below the top surface as a result of continuous use of the same type of machines and ploughing at the same level for a number of years.[10]

The clay soils on which mechanized farming is practised are considered good and deep, with good infilteration rate and moisture holding characteristics. Some research had demonstrated that these soils contain adequate amounts of phosphorus, but that the uptake of these nutrients depends on root depth. Application of phosphorus and nitrogen fertilizers showed varied responses from poor to excellent according to amount of rainfall received. More experimental work is needed on the application of fertilizers, especially for sorghum which requires a high amount of nutrients and is a shallow-rooting crop.

Crop production under rain-fed mechanized farming is low and variable from one year to another as clearly shown by the yield/feddan ratio for the years 1968/69-1980/81 provided on Table 6.5 for sorghum, Table 6.6 for sesame and Table 6.7 for cotton. The problem that concerns us is the fact that low productivity may be a result of many constraints other than degradation of soil fertility such as lack of proper extension work, low use of inputs such as fertilizers, pesticides and improved seeds, lack of capital, lack of agricultural machinery, spare parts, fuel, or rainfall variability (Tables 6.8, 6.9, 6.10 and 6.11). The presence of any of the above mentioned constraints may be enough to result in the yields shown on Tables 6.5, 6.6 and 6.7.

This is why research identifying the magnitude and role of soil degradation in the mechanized rainfed agricultural areas is urgently needed. Statistics show that some farmers produce higher yields than others, but that all production is low if compared with yield/feddan ratio for other countries with similar environments and conditions (Table 6.11).

TABLE 6.5

AREA, PRODUCTION AND AVERAGE YIELD OF MAIN CROPS UNDER RAIN-FED MECHANIZED FARMING (1969-1972/73)

PROVINCE	SEASON	SORGHUM (dura)			SESAME			COTTON		
		Area in Feddan	Production in Tons	Average Yield Ton/Feddan	Area in Feddan	Production in Tons	Average Yield Ton/Feddan	Area in Feddan	Production in Tons	Average Yield Ton/Feddan
Kassala	1969/70	1,343,988	327,318	0.243	321,924	51,459	0.159	63,640	4,051	0.0636
	1970/71	1,688,742	507,877	0.300	278,282	41,465	0.149	20,528	2,096	0.102
	1971/72	1,459,390	454,371	0.309	278,454	52,299	0.188	5,600	741	0.132
	1972/73	1,082,935	207,090	0.191	370,686	81,352	0.219	16,000	2,715	0.170
B. Nile	1969/70	187,001	63,998	0.342	46,065	6,331	0.137	---	---	---
	1970/71	257,520	125,123	0.486	25,735	3,665	0.142	---	---	---
	1971/72	300,714	128,191	0.426	33,056	4,933	0.149	---	---	---
	1972/73	370,095	116,009	0.313	101,216	11,707	0.116	---	---	---
S. Kordofan	1969/70	685	623	0.909	98	15	0.153	---	---	---
	1970/71	15,714	7,498	0.477	2,700	229	0.085	300	25	0.083
	1971/72	76,510	32,461	0.424	10,530	1,405	0.133	798	206	0.258
	1972/73	85,350	29,493	0.346	7,667	1,491	0.194	6445	1,982	0.308
Upper Nile	1969/70	60,000	27,273	0.455	8,000	541	0.068			
	1970/71	65,000	26,591	0.409	11,705	737	0.063			
	1971/72	127,260	57,755	0.454	10,530	1,405	0.133			
	1972/73	34,660	12,682	0.366	32,020	3,978	0.124			
White Nile	1969/70	---	---	---						
	1970/71	14,365	3,193	0.222						
	1971/72	43,765	8,047	0.184	160	1.5	0.009			
	1972/73	34,620	12,682	0.366	4,200	736	0.175			
S. Darfur	1969/70									
	1970/71									
	1971/72									
	1972/73									

TABLE 6.6

AREA, PRODUCTION AND AVERAGE YIELD OF MAIN CROPS UNDER RAIN-FED MECHANIZED FARMING (1973/74-1976/77)

PROVINCE	SEASON	SORGHUM (dura)			SESAME			COTTON		
		Area in Feddan	Production in Tons	Average Yield Ton/Feddan	Area in Feddan	Production in Tons	Average Yield Ton/Feddan	Area in Feddan	Production in Tons	Average Yield Ton/Feddan
Kassala	1973/74	1,388,500	444,614	0.320	441,500	71,559	0.162	20,550	4,133	0.201
	1974/75	1,815,700	445,917	0.245	374,000	25,040	0.067	8,800	1,041	0.118
	1975/76	1,944,455	796,415	0.409	302,550	26,759	0.88	18,000	1,774	0.099
	1976/77	1,915,690	571,848	2.299	400,000	53,900	0.135	15,600	3,114	0.200
B. Nile	1973/74	393,691	216,702	0.550	224,914	24,521	0.109	1,500	688	0.458
	1974/75	698,280	184,830	0.265	117,475	25,661	0.218	12,020	2,036	0.169
	1975/76	499,361	152,367	0.305	142,316	14,635	0.103	11,184	1,458	0.130
	1976/77	523,478	177,092	0.338	116,714	15,168	0.130	10,457	2,640	0.252
S. Kordofan	1973/74	122,285	30,844	0.252	9,986	956	0.095	12,033	883	0.073
	1974/75	159,528	39,216	0.246	24,544	1,587	0.065	7,813	1,646	0.211
	1975/76	181,920	65,132	0.358	20,984	1,648	0.078	3,000	25	0.008
	1976/77	193,181	85,815	0.444	24,075	3,042	0.126	3,500	375	0.107
Upper Nile	1973/74	253,755	109,770	0.433	49,820	4,618	0.093			
	1974/75	225,410	58,923	0.261	45,475	4,550	0.100			
	1975/76	318,605	136,408	0.428	47,110	2,774	0.059			
	1976/77	257,743	83,999	0.326	23,435	2,785	0.119			
White Nile	1973/74	53,070	20,455	0.385	5,300	685	0.129			
	1974/75	48,900	21,591	0.441	---	---	---			
	1975/76	51,020	32,030	0.628	2,500	50	0.020			
	1976/77	140,440	42,632	0.304	5,000	450	0.090			
S. Darfur	1973/74	1,400	109	0.078						
	1974/75	4,380	654	0.149	300	12	0.040			
	1975/76	4,400	177	0.040	400	25	0.063			
	1976/77	6,440	714	0.111	1,350	50	0.037			

TABLE 6.7

AREA, PRODUCTION AND AVERAGE YIELD OF MAIN CROPS UNDER RAIN-FED MECHANIZED FARMING (1977/78-1981/82)

PROVINCE	SEASON	SORGHUM (dura)			SESAME			COTTON		
		Area in Feddan	Production in Tons	Average Yield Ton/Feddan	Area in Feddan	Production in Tons	Average Yield Ton/Feddan	Area in Feddan	Production in Tons	Average Yield Ton/Feddan
Kassala (Gedanet)	1977/78	1,847,611	61,302	0.250	344,200	46,447	0.135	25,282	5,397	0.180
	1978/79	2,043,217	516,357	0.252	193,871	26,172	0.135	12,612	1,410	0.111
	1979/80	1,672,074	267,678	0.279	342,000	53,865	0.157	9,520	1,971	0.207
	1980/81	2,168,450	711,984	0.328	321,950	48,195	0.149	9,950	796	0.080
	1981/82	3,039,655	1,186,594	0.390	250,000	45,000	0.180	11,000	1,980	0.180
B. Nile (Damazin)	1977/78	491,011	161,786	0.329	186,535	20,221	0.108	16,180	2,388	0.145
	1978/79	335,990	88,155	0.262	65,264	5,969	0.091	16,025	2,736	0.170
	1979/80	251,664	77,724	0.308	87,826	10,408	0.118	25,757	4,212	0.163
	1980/81	187,120	46,420	0.248	69,475	8,200	0.118	60,633	11,018	0.181
	1981/82	1,568,700	784,350	0.500	152,450	27,441	0.180	46,540	8,377	0.180
S. Kordofan (Dilling)	1977/78	208,747	65,383	0.314	18,520	3,200	0.173	1,310	75	0.057
	1978/79	229,655	80,930	0.352	11,355	772	0.068	---	---	---
	1979/80	183,878	27,548	0.150	22,860	1,724	0.075	---	---	---
	1980/81	204,707	63,495	0.310	21,825	1,250	0.057	---	---	---
	1981/82	226,000	90,400	0.400	19,080	3,369	0.181	---	---	---
Upper Nile (Renk)	1977/78	261,757	98,095	0.375	33,980	4,083	0.120	---	---	---
	1978/79	286,242	124,280	0.434	28,768	2,021	0.070	---	---	---
	1979/80	198,220	84,791	0.428	55,695	5,005	0.090	---	---	---
	1980/81	204,935	72,863	0.355	57,099	3,836	0.067	---	---	---
	1981/82	480,300	232,180	0.483	20,000	3,600	0.180	---	---	---
White Nile (Kosti)	1977/78	125,000	50,000	0.400	---	---	---	---	---	---
	1978/79	136,550	56,428	0.413	850	81	0.095			
	1979/80	167,000	50,100	0.300	1,000	68	0.067			
	1980/81	148,350	41,373	0.279	1,000	23	0.022			
	1981/82	260,500	104,200	0.400	---	---	---			

Source: M.F.C., Agricultural Statistics Bulletin No. 2, November 1979, Khartoum
1 Ton = 1000 kilograms

TABLE 6.8

AVERAGE YIELD OF SORGHUM IN KILOGRAMS/FEDDAN AND RAINFALL

PROVINCE		1968 /69	1969 /70	1970 /71	1971 /72	1972 /73	1973 /74	1974 /75	1975 /76	1976 /77	1977 /78
Kassala	Rainfall	581	462.1	486.1	584.3	520.1	516.6	638.6	660.9	617.4	566
	Y/Fedd. (Kilograms)	305	243	300	309	191	320	245	399	299	250
B. Nile	Rainfall				611.6	602.3	675.8	588.3	644	595.8	678.7
	Y/Fedd. (Kilograms)				624	313	365	264	305	330	329
S. Kordofan	Rainfall				710.9	699.5	509.9	701.8	712.2	606.7	611.4
	Y/Fedd. (Kilograms)				424	346	252	245	358	444	314
Upper Nile	Rainfall	NA	NA	NA	NA	348.8	421.9	475.7	611.4	NA	NA
	Y/Fedd. (Kilograms)	NA	NA	NA	NA	433	366	260	428	NA	NA

1 Ton = 1000 Kg.

Source: M.F.C. Agricultural Statistic Bulletin, No. 2, November 1979, Khartoum.

TABLE 6.9

AVERAGE YIELD OF SESAME IN KILOGRAMS/FEDDAN AND RAINFALL

PROVINCE		1968 /69	1969 /70	1970 /71	1971 /72	1972 /73	1973 /74	1974 /75	1975 /76	1976 /77	1977 /78
Kassala	Rainfall mm	581	462.1	486.1	584.3	520.1	518.6	638.6	660.9	617.4	566
	Y/Fedd.	124	160	149	188	219	162	67	88	135	135
Blue Nile	Rainfall mm				611.6	602.3	675.8	588.3	644	595.8	678.7
	Y/Fedd.				149	116	109	218	103	130	108
S. Kordofan	Rainfall mm				710.9	694.5	509.9	701.8	712.2	606.7	611.4
	Y/Fedd.				133	194	96	65	79	126	123
Upper Nile	Rainfall mm					348.8	421.9	475.7	611.4		
	Y/Fedd.					124	93	100	59		

TABLE 6.10

AVERAGE YIELD OF COTTON IN KILOGRAMS/FEDDAN AND RAINFALL

PROVINCE	AVERAGE OF 14 YEARS	1968 /69	1969 /70	1970 /71	1971 /72	1972 /73	1973 /74	1974 /75	1975 /76	1976 /77	1977 /78
Kassala	Rainfall mm	581	462.1	486.1	584.3	520.1	576.6	638.6	660.9	617.4	566
	Y/Fedd.	112	64	102	132	170	201	118	99	200	180
Blue Nile	Rainfall mm				611.6	602.3	675.8	588.3	644	595.8	678.7
	Y/Fedd.						459	169	130	252	145
S. Kordofan	Rainfall mm				710.9	694.5	509.9	701.8	712.2	606.7	611.4
	Y/Fedd.				258	308	73	211	8	107	57
Upper Nile	Rainfall mm										
	Y/Fedd.										
W. Nile	Rainfall mm										
	Y/Fedd.										
S. Darfur	Rainfall mm										
	Y/Fedd.										

TABLE 6.11

Yield/Feddan for MF in Sudan and in Australia

CROPS	Y/F FOR SOME PLACE IN SUDAN OF MFC	Y/F FOR THE MAJORITY OF MF FARMS IN SUDAN	Y/F FOR RAIN-FED MF IN AUSTRALIA
Sorghum	0.7 tons	0.35 tons	2 tons
Cotton	5 small kontors	3.5 small kontors	7 small kontors
Sesame	0.2 tons	0.15 tons	---

Source: M.F.C. Managing Director's Report, 1982 (in Arabic).

small kontor = 45 kgs

ADEQUACY AND AVAILABILITY OF INFORMATION AND IDENTIFICATION OF INSTITUTIONS

It is necessary to mention that soil surveys were carried for most, if not all, of the areas under rain-fed mechanized farming before their development.[11] A detailed list for the areas covered by these soil surveys is given in a paper presented to the second conference of mechanized farming held at Khartoum in 1977, written by Mohamed Abdalla Ali. Reports of the long term experiments in Tozi 40 miles west of Abu Naama, and Gabub (near Gadaref) research stations provide good information on soils, production and weeds at those sites. The studies can be found at the library of the Faculty of Agriculture of Khartoum University. What is needed is a follow up of what has happened to the soils after a period of about 40 years of continuous mechanized rain-farming. Research in this area is just starting.

Regarding the capabilities and capacities of the institutions concerned with the problem, it seems that the universities, the Agricultural Research Corporation and the Soil Survey and Land Classification Division of the Ministry of Agriculture should have the capable staff and laboratories to carry out further research on the soils of the MF areas and monitor the degree and causes of degradation. These institutions will need financial support to update laboratory equipments and means of data collection and analysis. They shall also need sufficient and efficient transport, fuel and spare part supplies to be able to adequately cover an area of approximately 7 million feddans.

POLICY FORMATION, POLICY AND PROJECT IMPLEMENTATION AND EVALUATION

Policy formulation and project implementation and evaluation at present are the responsibility of the Mechanized Farming Corporation. This needs

M.F.C., and other departments such as Soil Conservation Department, Range Management Department and Forestry Department. Another important component of this integration is the farmer himself. He is ignorant, not concerned and, in most cases, unaware of the long term results of his practices and mismanagement of not easily renewable resources. The present extension services provided by the Ministry of Agriculture are quite inadequate. Project evaluation has been instituted only recently. As a result, the M.F.C. was advised by many consulting agencies to establish an extension division, which it did (Figure 6.1).

INTERVENTIONS: ACTIVITIES UNDERWAY TO COPE WITH THE PROBLEM

First, the problem needs evaluation. There is doubt that the preceding stage of evaluation is given adequate consideration. Consultants were invited by the Ministry of Agriculture to evaluate the performance of the MFC, and to make recommendations to promote the sector and the corporation in the hope of more agricultural productivity and contribution to the National Economy. P.A. International Management Consultants of 300 High Street Slough, England issued three reports of organization and management appraisals for the MFC in 1982. The World Bank was also invited to revise and review the performance of the Agricultural sector in general. The World Bank has been financially involved in the promotion and the rehabilitation of the mechanized sector since 1968 - 1973 (phase I and II projects). In its most recent involvement, the World Bank alloted an amount of 16 million U.S. dollars for the promotion of the existing and establishment of new research and experimental centres as well as the establishment of an efficient extension department (see Figure 6.1) responsible for soil conservation and to advise farmers in an effort to increase production. The vast extending M.F. farms make the farmers inaccessible during the rainy season. Unless adequate means of transport are made available, extension workers will not be able to do the job. Well trained and dedicated extension workers are badly needed.

Legislation to look after soil and resource conservation and to follow MFC regulations are clear and adequate as appear in the Mechanized Farming Public Corporation (Establishment) regulations, 1975 R.O No. 25. In the contracts for rent or lease, farmers are bound to follow the M.F.C. recommendation regarding soil conservation and resource management on pages 3 and 2 of the two contracts respectively. Unfortunately these rules are not enforced.

Figure 6.2 provides a detailed chart showing the organization of MFC, the existing and satisfactory posts and offices or divisions, the existing but not satisfactory posts, and the offices and divisions proposed by the consultants.

Quotations from pages 10 and 12 of the P.A. International Consultant's Report are attached to provide the details of the working force and to give an idea about the input resources, performances and capital.

SUDAN MECHANIZED FARMING CORPORATION ORGANIZATION 1982

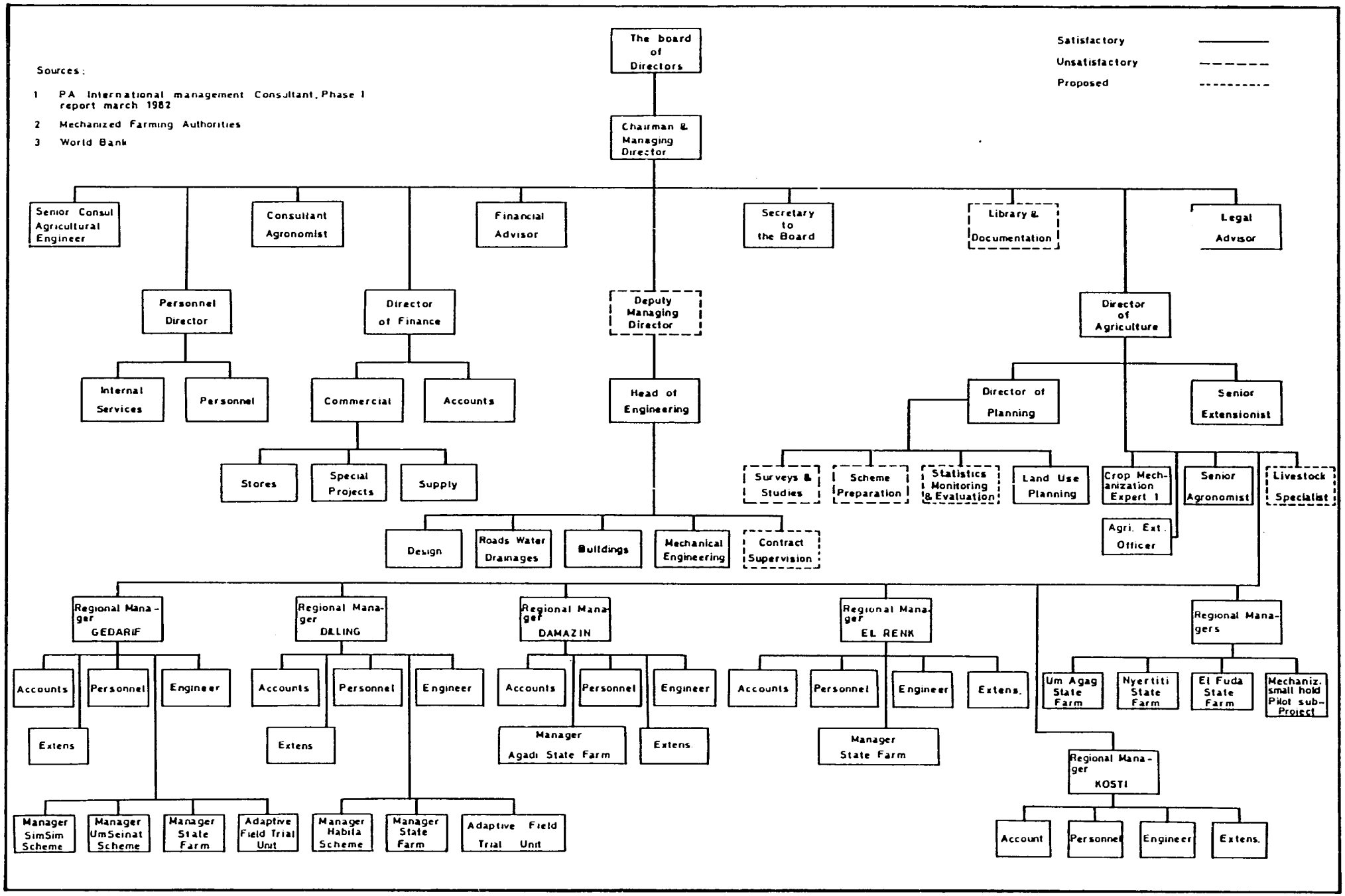


FIGURE 6.2

TABLE 6.12

MFC MANNING SITUATION

LOCATION	STAFF EMPLOYEE	WORKERS	TOTAL
Khartoum HQ	94	37	131
Gedaref	43	60	103
Simsim State Farm	13	27	40
Simsim Schemes	20	95	115
El Huri	6	14	20
Um Seinat Project	20	69	89
Nertiti/Um Agag S	14	11	25
Damazin	33	13	46
Agadi State Farm	42	200	242
Damazin Workshop	11	15	26
El Renk	18	8	26
Cozroom State Farm	13	47	60
Dilling	31	12	43
Habila State Farm	14	44	58
Habila Project	22	106	128
Kosti Project	7	4	11
El Fuda Scheme	6	-	6
TOTAL	407	762	1169

Source: International Management Consultants, Sudan Mechanized Farming Corporation Organization and Management Appraisal, Phase I Report, March 1982, p. 12.

Up to date figures on capital inputs are being worked out as part of the consultants' financial status report. As a broad indicator it has been discovered that of the £S 9 million invested so far MFC has lost all but 10 percent or £S 900,000 remains. The Corporation continues to lose about a million a year and is heavily dependent on Government subsidy to maintain its existence. Clearly a strong managemment lead is required to save the Corporation in the interest of the national economy.

The heavy machinery and agricultural implements situation provides a dismal picture. In Agadi (one of the state farms), of the 168 tractors only 68 were working at the last count. At Simsim state farm, 4 out of 40 Harvesters were working, the rest were sitting there as "junk." Vast amounts of these machines are lying idle for want of repairs and good maintenance. The situation in Agadi was described as a "machinery grave yard" - tractors with wheels missing, parts missing, "some machines dead, some alive." Whereas through a determined initiative tractors could be brought back to operation through

acquiring spares, and then rented to private farmers thus bringing in good returns on these investments. Similar arrangements would apply for discs, trailers, vehicles all of which could be rented bringing in a return. It is urgent that a thorough study of the position of workshop, machinery, implements and spares be carried out with a view to deciding the future of these activities vis-a-vis the long term aims of the Corporation.

Spares, fuel, shortage of funds, lack of planned maintenance and engineering management capability need urgent attention to improve the situation. Spares worth U.S. dollars 5 million will have arrived in Sudan by this year. Yet the black market situation indicates a serious lack of firm control in the distribution of spares on some priority basis. This in turn will mean land use will be seriously affected, fewer feddans will be cropped by the private farmers thus reducing output.[12]

Table 6.13 shows details of the available tractors and machinery, both working and broken.

GENERAL CONCLUSION

Mechanized rain-fed cultivation at its present form is a typical example of the dilemma of development versus conservation. Demand for sorghum to satisfy the needs of the increasing population is an urgent and complex problem as recognized by many decision makers. This results in the fact that they sometimes ignore or sacrifice the strict application of the best resource conservation methods. There is widespread ignorance of the magnitude of the problem of soil fertility degradation. The increasing involvement of the population in the market economy is one of the reasons. Large areas of flat land with good soil that are available at a competitive cost as well as the presence of a large domestic market for sorghum (the amount exported makes only 3 percent of the total country's production) contribute to the problem.

Sesame production is not very popular because it needs too many workers during the critical two weeks harvest. Seeds split and shatter if not harvested at the right time and the right stage of maturity. To increase the viability of sesame production and to encourage its introduction in the rotation, non-splitting varieties should be developed and made available to farmers. Mechanical harvesting should also be developed to avoid labour bottlenecks at the critical harvest time. At present, sesame accounts for only 10 percent of the total area cultivated under mechanized farming.

Cotton, the third crop under rain-fed mechanization is continuously losing ground. It is sensitive to pests and drought and needs a large number of workers for picking. Until recently, prices offered by the government did not make it worth the farmer's while although the internal market demand is growing. Mechanical harvesting is not economically feasible so far. The problems associated with other alternative crops explain the reluctance of private farmers to cultivate them as part of the rotation. Consequently, it is doubted that these alternative crops would be the solution for the soil fertility degradation problem, even when a powerful extension system is made available.

TABLE 6.13

MACHINERY, CARS, AND EQUIPMENT OWNED BY MFC AT DIFFERENT STATIONS

STATIONS	HEAVY TRACTORS		LIGHT TRACTORS		PICKUPS		LORRIES		DUMP CARS		HEAVY TRUCK		HARVESTORS	
	Running	Out of Order	Running	Out of Order	Running	Out of Order	Running	Out of Order	Running	Out of Order	Running	Out of Order	Running	Out of Order
Gedaref	13	3	157		23	4	12	5	9				20	39
Dilling	7		57		3	7	3	4					4	10
Damazin	5		100		11	4	14	8	2	2	6	4	14	36
Ngrtiti	-		10		3		2	2			-	-	1	-
Renk	-		20	8	2	-	-	2	2	2			1	10
Kosti	-		1	1										

Source: M.F.C. Authorities 1982/83

Solutions for the problem of low production and low soil fertility may be found by the introduction of new crops such as sunflower and soya beans on which some experiments were carried out. Use of herbicides to control weeds and the production of more improved sorghum and sesame varieties to be available for every farmer are essential. At present many farmers still grow low yielding traditional varieties because they cannot get hold of the improved varieties.

Discing and sowing are carried out by the use of a wheel tractor and a wide-level disc with seeder attachment. The first discing is carried out after sufficient rains fall. Soon after the first discing, another discing is carried out with the sowing done at the same time. It is thought that the resultant crop growth will be uneven with shallow root growth. Production may be good at the first two or three years after the land is first opened, but it starts to decrease because few inputs are added to improve soil fertility. No herbicides are used and weeding is done by hand and fertilizers are added. Some farmers use fungicide seed-dressings.

As a result, after eight or nine years, yields fall to an uneconomic level for the farmer and he either abandons farming completely or looks for other land to cultivate. The discussion supports the suggestion that more research should be done to improve the methods of tilling and the type of machinery used. More research is also needed for the provision of herbicides, fertilizers and the development of higher yielding sorghum, sesame, and cotton varieties. New crops which add to the soil fertility should be tried. The rate of horizontal expansion of rain-fed mechanized farming should be checked. There is a growing fear that it is going to expand at the expense of the forest and range lands. The degree of awareness of possible soil degradation as a result of mechanized farming should be increased both among authorities and farmers internationally. Specific research to look into causes and results of fertility degradation should be conducted. Monocropping, mechanical ploughing and rainfall variability are all blamed for soil and yield degradation. The exact causes are as yet unknown. To investigate the extent of the removal of plant cover a tree count in the mechanized area should be done. For this purpose an areal survey is needed.

NOTES

1. One feddan = 1.04 acre.

2. Mohamed A. Ali. 1977. "Soil analysis and land classification," a paper presented to the second conference on Machanized Farming, Khartoum (in Arabic).

3. Geography Department of Khartoum. May 1982. Environmental Context of Development in Sudan, Khartoum, p. 25.

4. Mustafa El Sayed El Khalil. 1981. "The Impact of Mechanized Farming on the soil-water balance of Simsim project." M M.Sc. dissertation, Institute of Environmental Studies, University of Khartoum, pp. 4, 5.

5. Tawfig Hashim Ahmed. September 1982. "The Modern Rainfed Agricultural Sector: Means of its Development, for the Rehabititation of the National Economy." The report of the Managing Director of the Mechanized Farming Corporation, Khartoum, (in Arabic).

6. Mahmoud Ahmed Mahmoud. 1977. "Agricultural Rotation in Rain Cultivated Lands." A paper presented at the 2nd Mf conference, Khartoum (in Arabic).

7. Scientific and traditional names of weeds.

8. Hassan Haj Abdalla, "The Manager of the Soil Analysis Section at Wed Medani Agricultural Research Centre".

9. This information was collected by an interview with Mohamud A. Mohmoud, the agronomist consultant to the MFC. Overwhelming run off occurred three times in the area at different rates and velocities, in 1969, 1973, 1979.

10. Salah El Din El Khalifa. 1977. "Agricultural Land Planning." A paper presented to the second conference of M.F., Khartoum (in Arabic).

11. Sudan, Ministry of Agricultural soil survey Division. October 1966. Nuba Mountains Survey, Part III Wad Madani 1963/64. NEDECO, ILACO Ministry of Agr. Southern Gedaref Soil Survey, Umm Simsim UMM Seinat Project MCPC Soil Survey and Land Classification Report, The Hague.

12. International Management Consultants. March 1982. Sudan Mechanized Farming Corporation: organization and management Appraisal, Phase I, Report, p. 10.

CHAPTER SEVEN

Chapter seven traces the spread of two diseases -- malaria and schistosomiasis -- and their relationship to the development of irrigation projects. Dr. Ahmed analyses the economic costs and benefits of control and eradication of these two diseases and their link to agricultural productivity.

Health Problems Arising in Irrigated Agricultural Areas

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INTRODUCTION

The health problems arising in irrigated agricultural schemes in the Sudan are closely related to the geographical, climatic, demographic and social characteristics as well as to the economic development of the country. Sudan, the largest country in Africa, covering a total area of 2.6 million square kilometers, is situated in the northeastern part of the African continent. The country's northern third is desert with annual rainfall of about 20 mm. Annual rainfall increases steadily from north to south to reach over 2000 mm in the tropical rain forests of the south. Temperatures are generally high throughout the year. Vegetation varies from the desert type in the north, to semi desert, to low wooded savanah and into the land of swamps, high wooded savanah and tropical rain forest. This climate greatly affects the major health problems and the formulation of their control measures.

The most recent population census was conducted in the Sudan in 1973. Using the best estimate of 2.5 percent growth rate, the population projection for 1983 would be 18,523,000 with an overall population density of 5.9 persons per square kilometer, with wide variation in spatial distribution. Urban, rural, and nomadic distribution of population, which varies widely between the

different provinces, is greatly affected by economic development. Persons of working age (defined as the 15 to 60 age group, though not all members of this group are economically active) comprise about 30 percent of the total population. Those in this age group are particularly affected by diseases, like schistosomiasis, which show high prevalence in most of the newly developed agricultural schemes.

Water resources development projects during the last sixty years brought about major environmental changes which greatly affect the incidence of malaria and schistosomiasis. Both diseases are still on the increase and their incidence is likely to continue to be on the increase so long as irrigation remains the major component of the country's potential for development.

Many health problems arise from the agricultural schemes. However, in the following pages attention will be paid to malaria and schistosomiasis which were given special emphasis in the National Health Programme of 1978 - 1984. Other health problems initiated or aggravated by the agricultural schemes will be briefly mentions.

MALARIA AND BILHARZIA

Malaria and bilharzia are considered major public health problems in the Sudan. Efforts to control them were started early within the medical services. However, in spite of the marked improvement is the control measures now available, statistics show that both diseases are on the increase (Table 7.1). In a country like the Sudan, with high agricultural potential and whose socio-economic development is closely tied to agricultural development, it becomes vital to maximise efforts to control these problems. Table 7.2 provides a breakdown of the incidence of the two diseases by province in Sudan.

MALARIA

Malaria is no doubt the most serious endemic disease in the Sudan, causing losses of efficiency and invaliding, increasing death rate and causing agricultural and industrial inefficiency. It is amongst the commonest causes of infant mortality. In the Sudan only three of the four malaria parasites are encountered (P. falcipan, P. vivax and plasmodium malaria) as plasmodium ovale is unknown in the Sudan.

About sixty years ago and before the beginning of the agricultural schemes the incidence of malaria was much more restricted than at present. In the northern part of the country where there is practically no rain, malaria was largely confined to areas along the Nile. The disease appeared during or soon after the annual flood when the Nile would recede leaving ponds which provided breeding places for the anophiline mosquito, the vector for the malaria parasite. In central Sudan, unstable malaria dominated. The disease appeared in the form of epidemics, usually during the rainy season. In the Southern parts of the country, where breeding sites were available and maintained throughout

TABLE 7.1

CASES OF MALARIA AND BILHARZIA

1973 - 1981

DISEASES	1973	1975	1976	1977	1978	1979	1980	1981
Malaria	818,225	937,776	399,762	1,030,243	1,045,840	2,665,753	2,830,931	2,981,052
Bilharzia	90,576	395,805	1,452	102,989	562,546	98,354	98,143	159,848

TABLE 7.2

DISTRIBUTION OF MALARIA AND BILHARZIA

BY PROVINCES IN 1981

PROVINCES	MALARIA	BILHARZIA
Khartoum	283,727	26,843
Gazira	428,645	75,168
Blue Nile	331,850	25,922
White Nile	260,168	15,028
Northern	43,146	756
Nile	59,414	3,220
Kassala	854,239	4,545
Red Sea	44,189	19
N. Kordofan	225,101	357
S. Kordofan	241,880	5,034
N. Darfur	113,823	1,097
S. Darfur	94,870	1,859
TOTAL	2,981,052	159,848

the year, there was perennial transmission and a more stable form of malaria was maintained.

This situation which dominated the country up to 1926 changed greatly after completion of the Sennar Dam in 1925 and the commencement of irrigation on large areas of relatively arid land. The principal source of mosquito breeding during the dry season became the field canals. The presence or absence of malaria during the dry season became dependent primarily on the condition of the field channels and the sepage from the canals. Then it was vital to suppress the incidence of malaria to ensure the success of the irrigation project.

Apart from the efforts undertaken to destroy the anophiline larvae by larviciding with heavy engine oil and screening houses to prevent the adult mosquito from entering, very strict measures were taken to minimise leakage of water from the canals in Gezira and other small schemes in the Northern Province (Gureir, Nuri, Zeidab). Anophiline gambiae and Anophiline fenustus are the main malaria vectors in the Sudan with the latter mainly responsible for transmission during the dry months.

Up to 1940 the malaria control activities were mainly centered around larvicide application to control anopiline mosquito through the control of its larval stage. Though successful in urban areas, the use of larvicides was not practical in the rural areas. By the 1950s anti-anophiline measures using residual insecticides had been widely used in the Sudan. BHC and DDT were both used and their effect was markedly noted in the following years when the annual malaria incidence dropped to one fifth of that recorded in any of the years before spraying (Sudan 1954). The disease which showed steady increase during the 1940s, reaching a peak of 8.3 percent in 1950, gradually receded to 2.7 percent of the total registered outpatients in 1963 due to the effect of the wide use of DDT and BHC.

By the late 1930s a network of dispensaries was established in the Gazira and other agricultural schemes; these helped greatly in the malaria control and in reducing mortality by providing treatment to the affected communities. In 1950s and with assistance from the W.H.O., a pre-eradication pilot project was started at Sennar in the Southern Blue Nile Province. However, after the pre-eradication survey was carried out, it became apparent that the health infrastructure was not sufficient to support a malaria eradication programme. The centre maintained its function as a malaria control training centre.

In 1973, after a thorough study of the difficulties that faced the pre-eradication programme, it was decided that the activities should be directed towards the control of malaria. A malaria department was established at the Ministry of Health Headquarters to undertake malaria surveillance activities, give advice on the control methods to be used and to evaluate the malaria control activities nationwide. The malaria division also participated in research activities concerning the monitoring of insecticide resistance and the use of biological methods used for the control of the anophiline mosquito.

As part of its activity the malaria division developed a protocol for control of A. gambiae in the northern part of the Northern Province. This activity has been carried out through a bilateral agreement between the Ministry of Health, Sudan and the Egyptian Ministry of Health. The activity includes biannual, regular inspection of the area reaching 180 miles South of Lake Naser. Breeding sites were detected and treated. It was hoped that this activity could be extended further south guarding against an A. gambiae movement into Egypt.

There is little doubt that malaria is the highest single cause of morbidity in the Sudan and is the greatest cause of human inefficiency. The man-made malaria (malaria produced or aggravated by agricultural practice) affect the GNP by reducing agricultural productivity. Hence malaria has economic as well as medical repercussions.

Agriculture accounts for 40 percent of Sudan's GNP. The Gezira is the largest agricultural scheme accounting for 60 percent of the Sudan's exports (mostly cotton). The economic losses resulting from malaria morbidity and mortality, apart from the cost of medical care needed for the treatment of malaria cases, have never been estimated in the Sudan. There is no doubt that productivity is highly affected by malaria. In the national health programme document of 1975, analysis showed that the minimum standard for cotton production in the Gezira irrigated area was 5 kantors per feddan but in 1973/74 total cotton production averaged only 4 kantors per feddan. Although several factors may have contributed to this reduction, investigation has revealed that the tenant's debility due to malaria constituted a major cause of the shortfall. In view of the average of 33 working days lost per tenant in 1973/74 due to malaria (sample survey) one can imagine the extent of losses in cotton production. On the other hand, analysis of the effect of malaria control shows that the reduction in the number of working days lost per tenant to 8 per annum would result in saving 3.8 million kantors of cotton annually. Use of control measures will result in marked financial benefits (Table 7.3). Apart from the relief of human sufferings, the benefit-cost ratio is estimated at 4.63:1.

The malaria control activities were very much affected by the appearance of resistance to DDT and other insecticides which were used for house spraying. The principal malaria vector, A. arabiensis, developed malathion resistance in the Gezira in 1978. This phenomenon gradually increased so that by 1979-1980 it was necessary to shift to tenitrothion (BNH).

The seriousness of the malaria situation in the Gezira area called for emergency measures. In 1975 an emergency campaign was developed to control malaria by:

1) Residual house spraying using malathion, tenitrothion and abate; and

2) Mass chemotherapy using presumptive dosage of chlorophine and pyremethamine. The agricultural use of insecticides in the Gezira has contributed to the development of resistance to these insecticides used for control of mosquito and co-ordination with the agricultural authorities has became a necessity.

TABLE 7.3

BENEFITS/COST (in £s Thousands)

1976/77	VALUE OF TENANT Gross Income Saved	VALUE OF TREATMENT COST AVOIDED	TOTAL	PROGRAMME COSTS	VALUE OF NET BENEFITS
1976/77	---	---	---	2,322.0	2,322.0
1977/78	2,036.0	35.1	2,071.1	2,001.0	70.0
1978/79	4,616.0	57.7	4,673.7	1,917.1	2,756.2
1979/80	6,528.0	48.3	6,576.3	1,867.0	4,700.3
1980/81	8,223,0	98.2	8,321.2	2,052.8	6,263.0
1981/82	9,740.0	128.1	9,868.1	2,096.3	7,771.8
1982/83	12,750.0	214.5	12,964.5	1,886.0	11,078.5
1983/84	19,238.0	267.5	19,505.5	2,007.0	17,498.5
TOTAL	63,131.0	849.4	63,980.4	13,836.2	47,816.3

Rate of benefits to costs: $\frac{63,980.4}{13,836.2} = \frac{4.63}{1}$

In its effort to guard against the possible serious effect of the increasing incidence of malaria and to ensure the maintenance of the effect of the emergency measures undertaken in the Gezira agricultural scheme, a special project was established in the area (The Blue Nile Health Project) and malaria was given high priority in the project (Figure 7.1). Apart from the services which it renders to the community, it provides opportunities for research work and evaluation of the different control measures used. The experience gained in this scheme is intended to be utilized in other agricultural schemes.

THE BLUE NILE HEALTH PROJECT

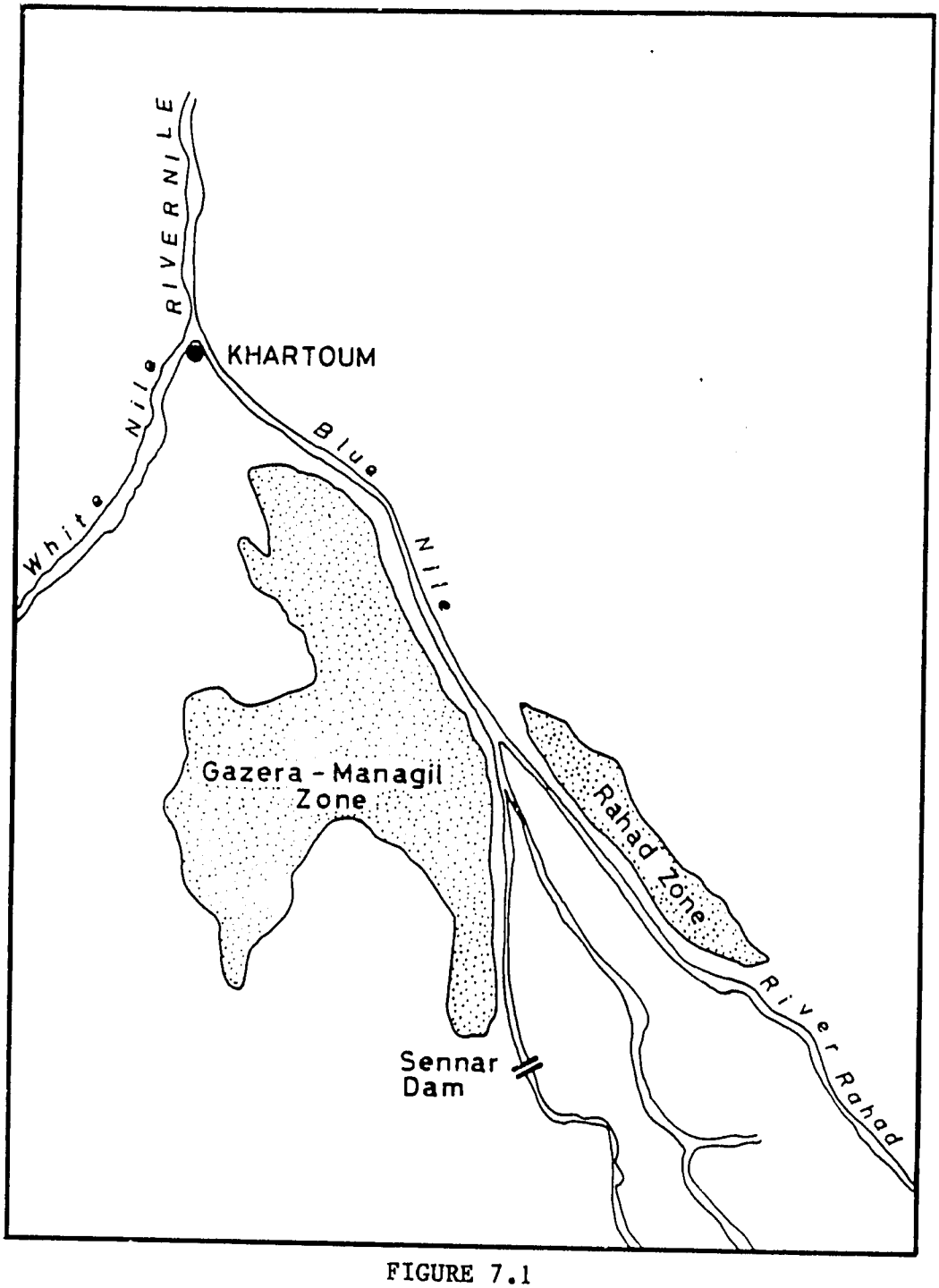


FIGURE 7.1

The effect of man-made malaria noted in the Gezira Scheme was similarly noted in New Halfa, where the Nubian population was resettled after the construction of the Aswan Dam in Egypt in 1963. Prior to the development of this scheme, malaria transmission, apart from the seasonal episode following the rainy season, was confined to the Atbra river basin. After agricultural schemes were developed, the malaria transmission was maintained throughout the year. The situation was further aggravated by the fact that the Nubians were non-immune, being transferred from a malaria-free area. Efforts made to control infection include:

1. Chemical control of mosquito,
   a. Malathion house spray,
   b. Abate;

2. Chemotherapy,
   a. Drug therapy,
   b. Drug proprophylaxis;

3. Environment managgement.

A marked increase in malaria incidence was noted in the area (Table 7.4).

Similar to the New Halfa agricultural scheme is the Rahad Agricultural Project which is a large agricultural development scheme. The project resulted in major changes in ecology and a marked increase in malaria transmission potential. To attain its socioeconomic objectives, it was necessary to anticipate the different health problems that were likely to arise and to minimize their effect as far as possible. This scheme was particularly fortunate in that several surveys were undertaken before its creation. Those surveys provided reasonably good base line data which would make it possible to evaluate control measures and to plan for the health activities required. The schemes come under the Blue Nile Health Project and are given due consideration in national health plans.

The malaria transmission increase was also notable in other smaller agricultural development schemes, like Suki, and the failure to plan before the schemes were established was well felt. There was also a marked increase in sugar producing development schemes like Guneid, New Halfa and Western Sennar. The effect of malaria was more evident in these industrial projects as it directly affects the labour force. Its effect on productivity was immediately felt.

BILHARZIA (Schistosomiasis)

It has been suggested by early health workers that schistosomiasis was introduced into the Sudan from Egypt (Archibald 1933). Prior to 1918 sporadic cases of schistosomiasis occurred at Berber, Dongola and Halfa areas in the northern parts of the country and in large towns where considerable contacts with Egyptians occurred (Sudan 1926). In 1921 a schistosomiasis haematobium epidemic was reported at Nuri and Gureir agricultural schemes in Dongola Province and at about the same time foci were discovered in other parts of the country.

TABLE 7.4

ANNUAL SLIDE POSITIVITY RATE OF MALARIA

IN HALFA RESETTLEMENT AREA AND RIVERAIN AREA

	HALFA RESETTLEMENT OF RIVERAIN AREA			HALFA RESETTLEMENT AREA			RIVERAIN AREA		
YEAR	No. of Slides Examined	Positive Slides	Percent	No. of Slides Examined	Positive Slides	Percent	No. of Slides Examined	Positive Slides	Percent
1966	17,896	752	4.2	5702	228	4	12,194	524	4.3
1967	18,873	1,806	9.6	11,470	918	8	7,304	888	12
1968	15,526	1,226	7.9	9,823	884	9	5,703	342	6
1969	27,255	2,350	8.6	19,444	1,944	10	7,811	406	5.6
1970	27,014	3,143	11.6	16,154	2,003	12.4	10,860	1,140	10.5
1971	18,021	2,198	12.2	10,806	1,621	15	7,215	577	8
1972	13,105	1,161	8.9	8,250	743	9	4,855	418	8.6
1973	12,538	1,224	9.8	8,664	953	11	3,855	271	7
1974	24,904	4,377	17.6	16,061	3,051	19	8,843	1,326	15
1975	36,757	5,419	14.7	27,294	4,094	15	9,463	1,325	14
1976	30,377	3,777	12.4	24,499	2,572	10.5	5,878	1,205	20.5
1977	33,452	2,377	7	29,187	2,043	7	4,765	334	7

In 1925 the Sennar Dam was completed and large scale irrigation was started in the Gezira area. This marked a new epoch in the history of schistosomiasis in the Sudan. From the inception of the scheme the possible serious repercussions of schistosomiasis were anticipated by the health authorities and various measures were taken to prevent the disease from finding its way into the newly irrigated areas.

It was decided that infected Egyptian labourers were to be prohibited from entering the small infested areas in the Gezira. Arrangements were made to treat them at Wadi Halfa before they were allowed to proceed southward. Similarly, measures were established at Kosti for the examination and treatment of all the passengers coming from western Sudan where a focus of schistosoma haematobium was known to exist. Surveys carried out at that time showed that there was low prevalence of the disease and over 90 percent of the cases detected were among immigrants from the western Sudan who were afflicted with schistosomiasis. Intermediate hosts for both type of schistosomiasis were known to exist in the area. With time, schistosomiasis mansoni became more and more dominant and today it is actually the most important type in the Gezira area.

In 1928 snails were detected in all the canals in spite of the fact that snail traps were used to prevent canal infestations. Copper sulphate was used as a molluscide and it proved to be effective. Copper sulphate continued to be the main molluscide till early 1970s when the work of Amin (1972) showed that N-trintyl morphline (Frescon) could be used. At present, a series of trials are in progress in the Blue Nile Health Project to determine the feasibility of applying bayluscide in target canal stretching along side the Gezira villages so as to keep village-water contact sites free from infected snails.

Since the establishment of the Gezira scheme, canal cleaning and removal of weeds had been practised annually. There is evidence that weed cleaning has a positive effect in reducing the snails in the canals. More recently the weeding of canals has been carried out mechanically and its effect on snails awaits evaluation.

As early 1981 Christophenson showed that antimony tartarate was an effective therapeutic agent for schistosomiasis. Since then the antimony compounds have become more extensively used for treatment of schistosomiasis. Recently, more effective, cheap drugs have been introduced. As these drugs are taken orally, they are likely to play a major role in the control activities. Several of these drugs are still under assessment in the BNHP.

Schistosomiasis control activities are mainly based on snail control, mass chemotherapeuties and the changes in the community's attitudes and behaviour through health education. Provision of safe water and safe refuse disposal systems plays a major role in the control activity. Discovery of the new safe oral effective drugs during the last few years has made it possible to control the disease through mass chemotherapy. The possibility now exists for an effective vaccine.

Because of the chronic nature of schistosomiasis, the assessment of its socioeconomic effects is more difficult than for malaria. The disease causes a lot of suffering and results in great losses in the working capability of the

farmers in the Gezira area. Though it causes low mortality, it saps energy and reduces resistance to other infections and, therefore, constitutes an important economic burden. As it infects the school age groups and young adults, it affects the school attendance of the children as well as the productivity of the young adults. Moreover, the treatment of patients is costly and the complications of the disease require hospitalization of patients which would overload the health institutions in the area.

Efforts were made to prevent the introduction of the snails into the canals in the Rahad Agricultural Scheme. However, the snails found their way into the canals. The pre-implementation multipurpose epidemiological survey carried out in the Rahad area showed that bilharzia cases were very few and were all among immigrant labourers who had been working in the Gazira area. The incidence according to a recent survey was high among young children indicating active disease transmission. As the Rahad area is included within the Blue Nile Health Project, active disease surveillance is undertaken and research activities to determine the most effective control measures are carried out (B.N.H.P.).

Shistosomiasis is also an important public health problem in the New Halfa agricultural scheme. Schistosomiasis mansoni is the main dominant there. As conditions are similar to those in the Rahad area, it is likely that measures applied in the Rahad area could easily be used for control of schistosomiasis in the New Halfa scheme and are likely to succeed in its control. Schistosomiasis is in fact a potential hazard in agricultural schemes depending on water from the Nile tributaries which are known to be infested with the intermediate host.

CONCLUSION

Though malaria and schistosomiasis are considered to be the main health problems associated with the irrigated agricultural schemes, there is no doubt that these schemes resulted in other health problems. Labourers migrating from the other parts of the country brought with them diseases not known to exist in the area before. Relapsing-fever was introduced from western Sudan in the 1930s and resulted in many deaths and established itself as an endemic disease in the area for a long time.

Migrants from western Sudan and West Africa also produced sickle cell disease - a haemglobinopathy - known to have a high prevalence among West Africans. Through marriages, the disease has become established in the area. Surveys taken around Gennar showed that the disease is prevalent among local tribes.

The ecological changes following the establishment of the agricultural schemes resulted in population coming into contact with areas previously uninhabited. This resulted in epidemic diseases like dermal leishmaniasis. Sudden changes of living habits have resulted in the same psychological changes as were demonstrated in the New Halfa scheme when the people were transferred from Old Halfa to the New Halfa area.

In conclusion, agriculture is the main constituent of the Sudanese economy employing about 70 percent of the country's labour force. Low productivity has a direct effect on the gross national product. It is quite evident that diseases affect the population in the most vital areas of the country, and lowers their productivity. Control and prevention of the water-related diseases form an essential component in planning the present and future agricultural development schemes.

APPENDIX

The Environmental Context of Development in Sudan

In 1982, specialists in the Geography Department, University of Khartoum and Clark University compiled a report entitled Environmental Context of Development in Sudan. The report directed attention to the environmental impacts of various development projects underway in the last few years in Sudan. The report indicates that the "environmental impacts of these development projects have become apparent in the form of resource degradation, devegetation, and signs of desertification. Thus there is great need for careful planning and monitoring of the environmental impacts of development, and the incorporation of environmental considerations into project planning."

Environmental problems can have considerable effects on the development process in Sudan. To assist in the productivity of development projects, especially on a long-term basis, the Environmental Context of Development in Sudan has attempted to provide some rating of the intensity of environmental problems in the various regions of Sudan.

The following is a summary statement taken directly from the above cited report. It is included as a strong expression of the Sudanese concern for the environment as well as providing guidelines for policy action concerning development projects in the Sudan. The map itself follows the explanation.

For the purpose of this map the environment is seen as a set of physical, biological, and social factors which influence a particular area or community. The interaction between these factors makes for a complex environmental system that needs careful analysis and monitoring. Development activities in the country can upset the delicate balance between these factors, and can present conflicts between satisfying social or economic goals and preserving a fragile physical environment. The most pressing environmental problems are those associated with declines in agricultural and livestock productivity such as vegetation cover removal which results from overcultivation or overgrazing, desertification, soil degradation, crop pests, animal disease and the general productivity declines associated with human morbidity and mortality.

The map is designed to present expected environmental trends at the regional level, and therefore, to alert planners and policy makers to environmental problems which can be considered either directly or as part of an integrated development programme. Thus, it is important that the map:

a. Show the present intensity of environmental problems at the district level,

b. Identify the kinds of environmental problems that are interacting in each district,

c. Show the possible environmental impacts of development projects at present and in the future.

In so doing, it is anticipated that the environmental map will create some awareness of environmental problems and their interactions at the district, regional, and national level so that environmental factors are taken into consideration in project planning.

Explanation of Map

Six categories of environmental problems were identified by members of the Geography departments of University of Khartoum and Clark University. For each of these categories data was collected at the smallest administrative unit, the census district. The data for each district was ranked and rated on a scale of 1 to 4 with 4 indicating more severe problems. The "total intensity rating" was the combination of the individual ratings for the six problem categories and was used to classify each district on the map. The total intensity rating is considered to show the degree of environmental pressure in that district.

The six problem categories used in this classification are:

1. Problems of Human Disease:

   This category includes the types of diseases present, as well as their incidence and prevalence. The incidence of particular diseases varies from district to district, so we considered the six major diseases associated with a given district.

2. Problems Arising from Livestock Diseases and Plant Pests:

   The category includes all diseases that affect domestic animals and was of special concern in areas with concentration of lifestock. Likewise, the presence and density of crop pests in agricultural areas were assessed and rated.

3. Land Related Problems:

   This category includes those problems related to land productivity. We included problems of soil fertility, problems of salinity, soil erosion and land characteristics which preclude cultivation. Each one of these problems was assessed separately.

4. Problems Related to Development Activity:

   This category includes problems related to the development process which includes urbanisation, industry and mining, and major agricultural projects, as well as the consequences of the lack of infrastructure and of isolation. For example, problems related to the development of agriculture included the impacts of irrigation on semi-arid environments and the consequences of the use of herbicides and pesticides.

5. Water Related Problems:

This category includes water quantity and availability, domestic water quality and problems related to periodic hazards such as floods and droughts. The numerical ratings for water quality represented a range from "very good" to "poor" while for flood and drought hazards the ratings denoted a scale from "light" to "severe."

6. People Related Problems:

This category includes the social factors related to resource use and access to the environment. We included land tenure problems such as fragmentation and open grazing. Other problems considered included land-use conflicts, deforestation as a result of overcultivation or overgrazing, and soil erosion as a result of human use of the land.

In producing the map, care was taken to simplify these complex problems in order to achieve a clear graphic expression of the environmental context of development in Sudan.

The key for the map categories follows:

Province/ District	Action	Pressure	Category of Problem(s)	Specific Problems
RED SEA				
1. Amrar & Bisharin	3	3	Development Activity/ Water Related/ Human Disease	Isolated, Lack of Infra-structure, Scarcity of Water, Drought, Malnutrition
2. Port Sudan*	3	3	Development/Water Related/Human Diseases	Urbanization/Industrial Development
3. Sinkat	2	2	Development Activity/ Water Related/ Human Disease	Isolated, Lack of Infra-structure, Scarcity of Water, Drought, Malnutrition
4. Tokar	3	3	Development Activity/ Water/Human Disease	Isolated, Lack of Infra-structure, Water Scarcity Drought, Malnutrition
KASSALA				
5. Aroma	3	3	Human Disease/Water/ People Related	Scarcity of Water, Drought Migration Dynamics, Land Tenure, Deforestation
6. Kassala	2	3	Livestock Diseases & Plant Pests/Development Activity/People Related	Plant Pests, Impact of Modernized Agriculture Migration Dynamics
7. New Halfa	2	3	Livestock Diseases & Plant Pests/Development Activity/People Related	Plant Pests, Impact of Modernized Agriculture Migration Dynamics
8. Gedaref North	3	3	Water/People Related	Water Scarcity, Water Quality, Land-Use Conflicts Deforestation
9. Gedaref Town*	3	3	Developmental	Urbanization/Human Diseases/Refugees
10. Gedaref South	2	2	People Related/Water/ Human Disease	Land-Use Conflicts, Migra-tion Dynamics, Water Scarcity Water Quality, Malaria
11. Qala en Nahl	2	2	People Related/Water/ Human Disease	Land-Use Conflicts, Deforest-ation, Water Scarcity, Water Quality, Malaria
GEZIRA				
12. Rufaa	3	2	Human Disease/Water/ People Related	Malaria, Schistosmiasis, Land-Use Conflicts, Deforesta-tion, Soil Erosion, Water Quality, Droughts
13. El Mielig	1	3	Human Disease/ Development Activity	Malaria, Schistosomiasis, Impact of Modernized Agriculture
14. El Mehiriba	1	3	Human Disease/ Development Activity	Malaria, Schistosomiasis, Impact of Modernized Agriculture
15. El Hasaheisa	2	3	Human Disease/ Development Activity	Malaria, Schistosomiasis, Impact of Modernized Agriculture
16. El Manaqil	2	3	Human Disease/ Development Activity	Malaria, Schistosomiasis, Impact of Modernized Agriculture
17. El Hosh	1	3	Human Disease/ Development Activity	Malaria, Schistosomiasis Impact of Modernized Agriculture
18. Wad Medani Town*	2	3	Development Activity	Urbanization Industrialization

BLUE NILE				
19. Sennar	2	3	Human Disease/ People Related	Malaria, Deforestation
20. Singa	2	3	Human Disease/ People Related/Water	Malaria, Land-Use Conflicts, Deforestation, Water Quality
21. Rufaa Sharig	2	3	Development Activity/ Human Disease/Livestock Diseases & Plant Pests	Isolation, Lack of Infrastructure, Malaria, Animal Disease
22. Er Roseires	3	3	Human Disease/Livestock Disease & Plant Pests/ Development Activity	Malaria, Lack of Infrastructure, Isolation
23. El Kurmuk	2	2	Development Activity/ Human Diseases/Livestock Diseases & Plant Pests	Isolation, Lack of Infrastructure, Malaria
24. Abu Higar	3	3	Development Activity/ Human Diseases/Livestock Diseases & Plant Pests	Isolation, Lack of Infrastructure, Malaria
WHITE NILE				
25. Kosti	3	3	Livestock Diseases & Plant Pests/People Related	Land-Use Conflicts Deforestation
26. Kosti Town*	3	3	Development Activity	Urbanization/ Industrial
27. Ed Dueim	2	2	Livestock Diseases & Plant Pests/People Related	Animal Diseases, Deforestation
KHARTOUM				
28. Khartoum	2	3	Development Activity	Urbanization, Industrial and Mining
29. Three Towns*	3	3	Development Activity	Urbanization, Industrial Development
NILE				
30. Shendi	2	2	People Related/ Development Activity/ Land Related	Land Tenure, Migration Dynamics, Lack of Infrastructure, Land Characteristics Preclude Cultivation
31. Atbara Town*	2	2	Development Activity	Urbanization
32. Berber	2	2	People Related/ Land Related	Land Tenure, Migration Dynamics, Land Characteristics Preclude Cultivation
NORTHERN				
33. Sukkot & Menas	1	1	Development Activity	Urbanization
34. Dongola	2	2	People Related/ Development Activity/ Land Related	Land Tenure, Migration Dynamics, Isolation, Lack of Infrastructure, Land Characteristics Preclude Cultivation
35. Merowe	2	2	People Related/ Development Activity/ Land Related	Land Tenure, Migration Dynamics, Isolation, Lack of Infrastructure, Land Characteristics Preclude Cultivation

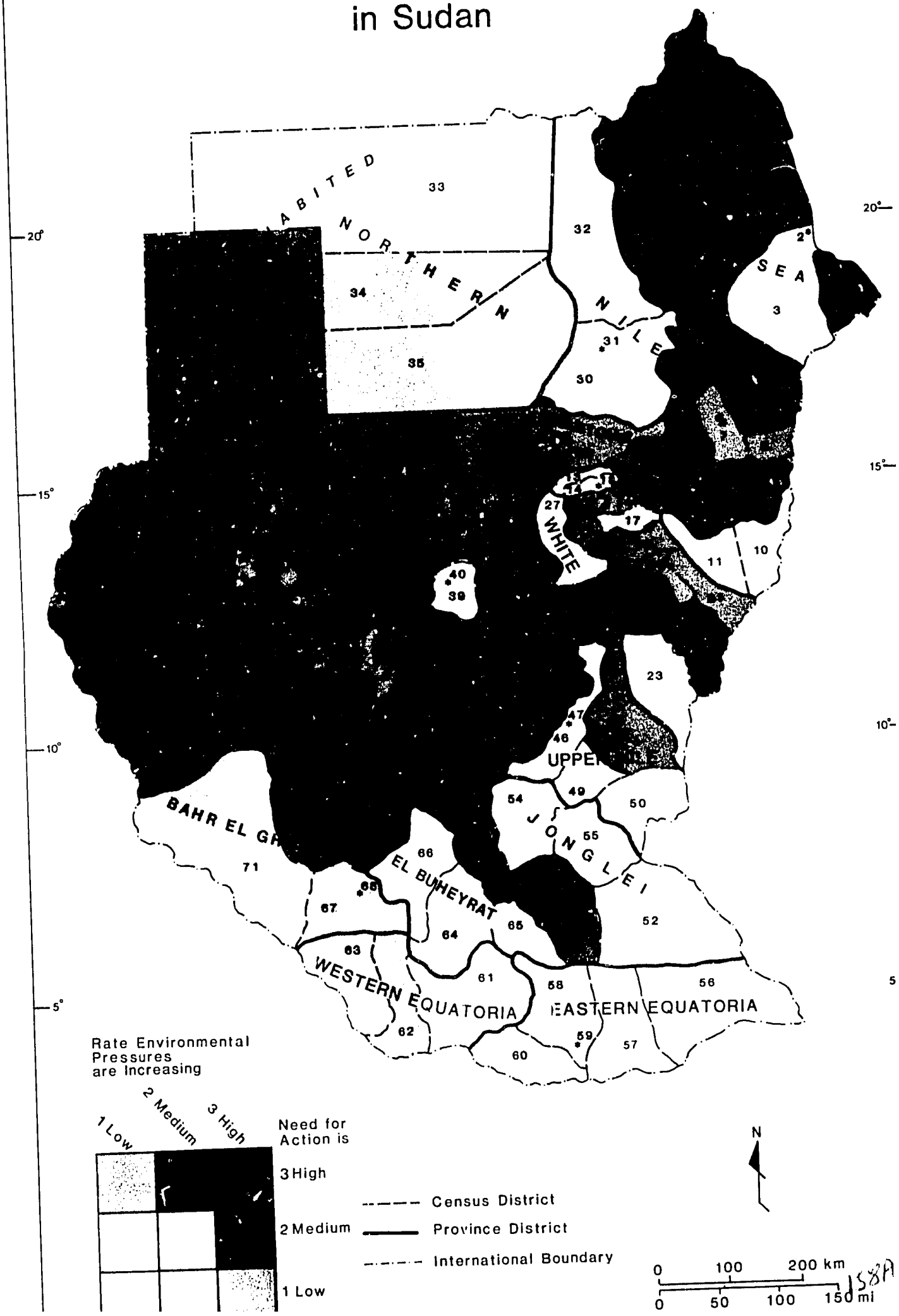
NORTHERN KORDOFAN				
36. Kababish	2	3	Water/Development Activity/People Related	Water Scarcity, Water Quality, Drought, Lack of Infrastructure, Isolation, Deforestation, Soil Erosion
37. Dar Hamid	2	3	Water/Development Activity/People Related	Water Scarcity, Drought, Isolation, Lack of Infrastructure, Deforestation, Soil Erosion
38. Eastern Kordofan	2	3	Water/People Related	Water Scarcity, Drought Deforestation, Soil Erosion
39. Bedeiriya	2	2	Water/Development Activity/People Related	Water Scarcity, Drought, Lack of Infrastructure, Deforestation
40. El Obeid*	3	3	Water/Development Activity	Water Related Diseases Urbanization
41. En Nahud	2	3	Water/Development Activity	Water Scarcity, Water Quality, Drought, Isolation, Lack of Infrastructure
SOUTHERN KORDOFAN				
42. Mesiriya	2	3	Development Activity/ Water/Livestock Diseases & Plant Pests	Isolation, Lack of Infrastructure, Water Scarcity, Water Quality, Livestock Diseases
43. Northern Jebels	3	3	Human Disease/ Development Activities, Water	Isolation, Lack of Infrastructure, Water Scarcity, Water Quality
44. Southern Jebels	3	2	Human Disease/ Development Activity/ Water	Isolation, Lack of Infrastructure, Water Scarcity, Water Quality
45. Tegale	3	2	Human Disease/ Development Activity	Isolation, Lack of Infrastructure
UPPER NILE				
46. Shulluk	2	2	Human Disease/Animal Disease & Plant Pests/ Development Activity	Isolation, Lack of Infrastructure, Malaria
47. Malakal Town*	2	2	Development Activity Human Diseases	Urbanization, Lack of Infrastructure
48. Renk	2	3	Human Disease/Livestock Diseases & Plant Pests/ Development Activity	Malaria, Isolation, Lack of Infrastructure
49. Sobat	2	2	Livestock Diseases & Plant Pests/Development Activity/Human Disease	Isolation, Lack of Infra structure, Malaria
50. El Nasir	2	2	Livestock Diseases & Plant Pests/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
51. Bantiu	3	3	Water/Development Activity/Plant Pests & Animal Diseases	Water Quality, Floods, Isolation, Lack of Infrastructure
JONGELI				
52. Bibor	2	2	Plant Pests & Animal Diseases/Development Activity/Human Disease	Lack of Infrastructure, Isolation, Malaria
53. Bor	2	3	Development Activity/ Plant Pests & Animal Diseases/Human Disease	Isolation, Lack of Infrastructure, Malaria, Venereal Disease
54. Zaraf	2	2	Water/Development Activity/Plant Pests & Animal Diseases	Water Quality, Floods, Isolation, Lack of Infrastructure
55. Lau Nuer	2	2	Livestock Diseases & Plant Pests/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria

EASTERN EQUATORIA				
56. Eastern Equatoria	2	2	Plant Pests & Animal Diseases/Development Activity	Lack of Infrastructure, Isolation
57. Torit	1	2	Human Disease/Development Activity/Plant Pests & Animal Diseases	Malaria, Isolation, Lack of Infrastructure
58. Juba	2	2	Human Disease/Development Activity/Plant Pests & Animal Diseases	Malaria, Isolation, Lack of Infrastructure, Urbanization
59. Juba Town*	3	3	Development Activity	Isolation, Lack of Infrastructure, Urbanization
60. Yei	1	2	Plant Pests & Animal Disease/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
WESTERN EQUATORIA				
61. Maridi	2	1	Plant Pests & Animal Disease/Development Activity	Lack of Infrastructure, Isolation
62. Zande East	2	2	Plant Pests & Animal Disease/Development Activity	Isolation, Lack of Infrastructure
63. Zande West	2	2	Animal Disease & Plant Pests/Development Activity	Isolation, Lack of Infrastructure
EL BUHEYRAT				
64. Rumbek	2	2	Plant Pests & Animal Disease/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
65. Yirol	2	2	Plant Pests & Animal Disease/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
66. Thiet	1	2	Plant Pests & Animal Disease/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
BAHR EL GHAZAL				
67. Wau	2	2	Human Disease/Plant Pests & Animal Disease/Development Activity	Malaria, Onchocerciases, Isolation, Lack of Infrastructure
68. Wau Town*	3	3	Development Activity	Urbanization, Lack of Infrastructure, Isolation
69. Gogrial	2	3	Plant Pests & Animal Disease/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
70. Aweil	2	3	Human Disease/Plant Pests & Animal Disease/Development Activity	Malaria, Onchocerciasis, Isolation, Lack of Infrastructure
71. Raja	2	2	Plant Pests & Animal Disease/Development Activity/Human Disease	Isolation, Lack of Infrastructure, Malaria
SOUTHERN DARFUR				
72. Southern Darfur	2	3	Development Activity/Livestock Disease & Plant Pests/Water	Isolation, Lack of Infrastructure, Livestock Disease, Water Quality
73. Western Darfur	3	3	Development Activity/People Related/Land Related	Isolation, Lack of Infrastructure, Land Tenure, Land-Use Conflicts, Migration Dynamics, Soil Erosion, Land Characteristics Pre-Clude Cultivation

NORTHERN DARFUR

74. El Fasher	3	2	Water/People Related/ Development Activity	Water Scarcity, Water Quality, Drought, Deforestation, Soil Erosion, Isolation, Lack of Infrastructure
75. El Fasher Town*	3	3	Development Activity	Urbanization, Lack of Infrastructure, Isolation
76. Eastern Darfur	2	3	Water/Development Activity/People Related	Water Scarcity, Drought, Isolation, Lack of Infrastructure, Deforestation
77. Dar Masalit	3	3	Development Activity/ Human Disease/Water	Isolation, Lack of Infrastructure, Water Scarcity
78. Northern Darfur	3	2	Water/Development Activity/People Related	Water Scarcity, Water Quality, Drought, Isolation, Lack of Infrastructure, Soil Erosion, Migration Dynamics

Environmental Context of Development in Sudan



158A

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