RESOURCE MANAGEMENT IN THE SUDAN: THE CASE OF THE GEDAREF REGION

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A B S T R A C T

This study reviewed the situation of natural resources management in the Sudan. It pointed out clearly, the negligence of natural resources in development plans; the lack of co-ordination between governmental institutions responsible for management of natural resources and the weakness of the entire system; the inefficiency of laws and lack of will for implementation of these laws and regulations.

For this part of the study, documentary sources and interviews with the planners (decision-makers) found to be an important source for providing the necessary information. The Gedaref District in Eastern Sudan was selected for study to analyse the impact of weakness in resource management on natural resources at the local level.

The parameters used for the assessment of the impacts of mechanised rainfed farming and the management practices of the farmers in the district were:
1) physical and chemical analysis of the important nutrients in the soil,
2) soil resistance to penetration,
3) drop in yield per sower,

4) interviews with the local peasantry.

Statistical analysis is used to show the significance of degradation in soils and its effect on yield and come to conclude that environmental resources in the study area is degraded as shown in overgrazing or pastures, deforestation, soil degradation, drop in yields and consequently desan
tification of large arable land in the district.

The study recommends that priority should be given to a co-ordinating institutional structure, backed with proper machinery of control and environ-
mental education to enable proper environmental mana-
gement at all levels of action.
تستمر هذه الدراسة الطريقة التي تعار بها الوقود العضوي في السودان، وتوجج جلياً التجهيز الكامل في خطط القبطة، وعندما اندمجت الانتقادات بين الإدارات ذات الاهتمام، واضطرت إلى الاختيارات كثر في هذا المجال، كما أن هناك قضايا تتعلق بثقة الإدارة التي تعتمد استعمال الوقود، وتظل هذه الوضعية في لنادين:

1. التحليل السربطي، والكيماوي، لمساواة النهوضية السببية.
2. خطة القبلية، وسلامتها.
3. الاختيارات في التأسيس للذبابة.
4. استناداً لإعداد الموارد في الدائرة.

ويعتبر الدراسات في التحليل الاحصائي على الوضعية الجيدة لدرجة التحسن الذي عاشه الوقود من الناحية الإنتاجية، وفضلًا أن الدراسات الهيكلية في منطقة تحديد الحياة، فيما يبداء آخرها، كما ذلك بأدلة، في نسخة الله ترضى الآخر، ويجب أجراء كتبة من الدائرة.

في خليفة، أو كما يقولون، يجب أن تكون دراسة الموارجع للأندية والخلاطر على قاعدة التعلم والإفادة البيئية من اجتنب ان تقرأ القبطة بطريقة سريعة على الأدبيات. وظائفية.
CHAPTER I
Environmental Management
Theory and Practice

1.1 Introduction

The aim of this chapter is to discuss some elements of the environmental management aspects such as policies, regulations and institutional aspects. It also looks into the experience of some developing countries in Africa and compared with other developed countries. Such a discussion provides an important background for the evaluating of local experience in natural resource and environmental management which will be elaborated in chapter III.

1.2 Environmental planning and Management

Traditionally, environmental resources were classified as "free goods" i.e. common property resources for which no ownership were identified. The growing population and exploitation of the environment imposes greater strain on these resources. Consequently there is an emphasis placed on resources
management in the light of severe environmental degradation such as deforestation and desertification which have resulted in flooding, reduced food production and eventually increased poverty and hunger. Misuse and irrational use of natural resources in the name of development is thought to be behind these problems. This is because, until recently, development was dominated by short-term planning and considered only as an increase in the national income.

These problems which arose from the process of development affected all developing countries and Sudan is not an exception. Many attribute the environmental problems we face to inadequate environmental concern in the planning process. This is because, political priorities concerning the allocation of natural resources are frequently dominated by physical planning and short-term economic consideration (Baker and Kinyanjui, 1980).
Experience of other countries has proved that "development" which ignores the effects it might have on the environment can cause waste of natural resources. As it is stated by the United Nation Conference on the Human Environment (1972) the environmental concern is only another dimension of the problem of development in developing countries and cannot be viewed separately from their development efforts. This conference also outlined two major aspects to deal with environmental issues in development. The first of these would involve an attack on the environmental problems that beset poor societies, and the other aspect is relevant to the need for the awareness of these problems that may arise in the process of development. However, alleviation of poverty is considered more difficult than preventing environmental deterioration, but if the current concern for the environment is not translated into actions, the task of preventing poverty will become even more difficult (World Bank, 1979).

Michael G. Ruyton, 1970 raised the issue of environmental oriented development and he specified
that development must be oriented towards human needs in terms of:
- greater involvement through the political and spatial environment;
- greater conviviality through the social and urban environment;
- more appropriate education through the cultural and scientific environment;
- better health, shelter and nourishment through the physical environment (land, air, water, housing);
- better employment through the economic and technological environments;
- more appropriate technology through the technological and scientific environment. p. 44

But, many emphasized the difficulty of establishing this broad environmental planning and attributed this difficulty to lack of public awareness for the potential benefits of broad planning and to conflicts among agencies involved in the planning process.
Only recently in developed countries, and as a result of general public awareness that, the planners began supporting environmentally sound development based on rational use of resources and "emerged what is now termed environmental planning and management as a new approach that assesses development projects from environmental point of view" (Inamad, 1984).

This approach may be described as the type of planning that tries to find the best method for utilizing natural and human resources in an integrated approach without exceeding the ecological limits. It is described by Lutting (1975) as "an art of careful handling of natural resources. At the same time it is a skill to cure nature which has been blighted and spoilt, and restore its potential for another better use".

This type of planning is based on environmental considerations as well as economic and social costs, which are seen as essential components in an overall national development planning and become an integral part of the multiple dimension of development.
strategy. Accordingly, Dr. Tolba (1981) considered recognition and reflection of environmental considerations at every stage of development as the practical essence of environmental management.

Thus, environmental management is seen as providing the tools and methodologies for sound utilization of resources which combines sustainability with optimum yield. To achieve this it becomes necessary that methodologies for environmental assessment and monitoring must be devised with the aim of incorporating the results of such assessment in development programmes (Fig 1).

Fig. 1 clearly indicates that sound environmental management requires environmental knowledge, environmental analysis and monitoring so that policy makers can translate these into practical actions for conservation and enhancement of human and physical environment.

Studies dealing with the issue of environmental management viewed it as composed of complex interrelated subsystems and so it requires an integrated
cross sectoral approach. The subsystems identified as including social, technical, political, legal, ecological and economic factors. The integration of these in a plan, present decision-makers and planners with their main problems and tasks.

Integrated planning approach as integral part of environmental management is based on how to manage resource use activities in order to achieve an acceptable balance between the quality of life and quality of natural environment (Fig. 2).

According to Bishop and Haryono, R, 1978 this involves three interrelated components: physical methods (e.g., production process changes, recycling, waste treatment); implementation incentives (e.g., air and water quality standards, discharge standards, effluent charges, taxes, subsidies); and institutional arrangements among responsible agencies.

For environmental management to achieve its goals of optimum and balanced allocation of resources over time, for the benefit and future generations, certain elements must be considered:
FUNCTION OF THE NATURAL ENVIRONMENT AND THEIR RELATIONSHIP WITH ECONOMIC ACTIVITIES

SOURCE: Rahat Ahmed (1983);
Modifying the Environment, BNEP
i) clearly stated environmental policy,
ii) comprehensive unified regulations, and
iii) an integrated and co-ordinated administration.

These issues will be briefly discussed in the following sections:

1.2.1 Environmental Policy

A policy statement need to be supported by legislations. Acts usually declare a policy to support and promote general welfare and to maintain conditions under which man's activities can co-exist in harmony (Huller, 1981). Thus, the national environmental policy should emphasize the necessity for wise use of total natural resources with special stress on the conservation (wise use) of natural resources to achieve a higher quality of environment.

The declaration of an environmental policy and the creation of an appropriate institution to execute that policy is the first step in making the government the real guardian or trustee of the country's resources in any workable sense (Seker
and Kinyanjui, 1980). But, in reality many developing countries have only fragmented policies on a wide range of issues i.e. sectoral policies. This lack of unified policy might result in one unit engaging in activities which are prejudicial to the environmental policies of another unit. Thus, an environmental policy must be seen in overall national development planning and must be applied to all governmental levels, national, regional and local.

A basic component of any environmental policy is the requirement for environmental impact assessment (E.I.A.) before implementation. E.I.A. is defined by Hollick (1980) as: "...act of processes for ensuring that environmental factors are given adequate considerations in making decisions on major proposals." Such regulation, imposes an obligation on developers (whether in public or private sector) to provide adequate information on the potential impacts of the proposed projects on the environment. So that remedial measures be incorporated in the project design to minimize the negative environmental impacts. Such assessment normally involves the consideration
of costs and benefits of the proposed activity on future trends of change.

Also, in order to have a concrete development plan the E.I.U. should be conducted in a linked and co-ordinated manner, at each significant stage (Fig. 3.).

1.2.2 Environmental Law

Environmental policy is clearly tied to the formulation of appropriate laws and regulations and ways of implementation. On the other hand, legislative bodies should develop and adopt laws with sufficient knowledge of scientific, economic and social aspects of the environment, so it is agreed that legal, technical, and economic experts must collaborate if there is to be effective environmental law. Such collaboration will ensure that the laws and regulations to be adopted will include ecological, economic, and social aspects. It is also expected that it will clarify the policy objectives and avoid setting conflicting goals. However, environmental laws and regulations should be considered as an
FIG (3) CATEGORIES OF ACTION AND LEVEL OF GOVERNMENT (PUBLIC AUTHORITIES) WITHIN A COMPREHENSIVE EPA

VOL. 34.
integral part of the process of formulating and developing policies for the environment and should be involved in every stage of the process.

The process of developing environmental legislation must be based on scientific principles, such as problem identification and data collection, followed by development of policy options for the decision makers to formulate the law and its enforcement method. The formulation of a comprehensive environmental legislation is required to give effect to the environmental policy, to establish environmental quality standards and to institutionalize the environmental impact assessment procedures. But, for legislations to be successful the need for it must be understood by those it affect. So, appropriate legislation must be backed by educational measures of various kinds, designed to reach all sectors of the community.

Another aspect of support for the environmental legislations process is the creation of environmental machineries to co-ordinate the various environmental
activities carried out by various departments within a country. These machineries can assist the environmental legislators in designing the law and providing advice for effective law enforcement to protect the environment.

1.2.3 Environmental Administration:

Once a country has integrated the environmental issues in its framework of development planning, and undertaken studies of specific policy actions required at the national level, concrete institutional arrangements would be needed to implement policies of environmental control. However, there is not a definite institutional arrangement which suits all countries. In any case, each country should devise its own institutional arrangements for environmental control in the light of its own needs and requirements as they emerge in the course of development.

Many governments administer environmental problems through traditional agencies e.g. Department of Health, Agriculture, Forestry ... etc. A major
disadvantage of such administration is the piecemeal policies followed. Such policies while appearing to be individually sound, may later prove collectively to be harmful to the environment. Almost always there is duplication of efforts with resultant dispute (J. C. Beale, 1980). So, integrated resource management while recognizing the existence of many institutions working in the field of environment, tries to provide the mechanism that ensures the cooperation of these institutions.

For instance, the principal aim of any national system should be to fit the decision making structure as closely as possible to the real nature of the problem. This implies that, the institution structure should have real strength efficiency to establish good horizontal linkage and really involve people in the field. So, local environmental problems can be handled on national basis, and thus result of research can be effectively incorporated into government policies. At the higher level, this structure should overcome interministerial and institutional
differences and become the guardian of the nation's resource base. It would propose policy and legislation on related issues and ensure good working group with all ministries. According to Mohamed, 1984 such an administration or an institution would require an environmentally aware planner and highly qualified staff to carry out interrelated activities addressed to it (Fig. 4).

1.3 Environmental management: Experience of other countries:

1.3.1: Kenya:

1) Environmental problems:

Kenya enjoys a great ecological diversity. The complexity of environmental problems is derived from both this diversity of conditions and from degree of development achieved. The country is characterized by heavy concentration of populations in limited high potential areas.

According to 1979 census, the rate of population growth is alarming. It showed that the rate of increase was 1.9 per cent per annum. The
FIG. (4) SOME INTER-RELATED ACTIVITIES OF AN ENVIRONMENTAL ADMINISTRATION PROCESS

NATIONAL ENVIRONMENTAL INTEREST

Other National Objectives

NATIONAL ENVIRONMENTAL OBJECTIVES

NATIONAL ENVIRONMENTAL POLICY

ENVIRONMENTAL LAW AND ADMINISTRATION

National Economic and Social Planning

ENVIRONMENTAL PROGRAMME BUDGET

ENVIRONMENTAL PROGRAMME SPECIFICATION

PROGRAMME ADMINISTRATION

RECOMMENDATION - REVIEW EVALUATION

IMPLEMENTATION

SOURCE: J. G. Rees (1980), Manager and the Environment
environmental consequences of this high rate of population growth could be summarized in the following:

a) Deterioration of land productivity through overuse and misuse.

b) Problems arising from the increased application of modern technology to agriculture such as increased use of pesticides and pollution arising from agricultural processing.

c) Distraction as a result of cumulative effect of overstocking and overgrazing.

ii) Environmental Administration:

In 1974, a National Environmental Secretariat (NES) was established in the office of the President and later moved to the newly created Ministry of Environmental and Natural Resources. The functions of the NES as an administrative department were:

a) to review and appraise the various proposed and existing projects from an environmental point of view;
b) to conduct investigations, studies, surveys, research and analysis relating to ecological systems and environmental quality;

c) to document and define changes in the environment and to analyse and evaluate these changes or trends and the interpretation of the underlying causes;

d) to ensure the inclination of environmental dimensions in the development planning exercise and in the design and implementation of projects.

In 1981 Kenya's experience was assessed and a national environmental policy was declared outlining the responsibilities of the different ministries in the field of environmental protection. In fact, lack of clearly defined responsibilities and the will to enforce the different environmental laws contributes effectively to the environmental problems the country faces. Taking into consideration all these facts, the National Enhancement and Management
Bill was drafted to ensure the enforcement of the national environmental policy.

Kenya efforts in the field of environmental management clearly indicated the degree of public and official concerns. Such concerns manifested themselves in the involvement of non-governmental organizations in the field of environmental protection. Kenya Women's Association sponsoring the Green Belt movement and placing much efforts in building nurseries in villages and in schools as well as informing the villagers of proper conservation practices.
1.1.2 Environmental Protection in Botswana:

Botswana's experience in the field of environmental protection is still at its infancy. Environmental matters are dealt with sectorally by various ministries and departments. Some efforts are exerted in the fields of water and air pollution.

The Water, Apportionment Board and Air Pollution Inspectorate detailed environmental assessment before approving any development activity. On the other hand, and in the field of natural resources protection, there are some legislations and regulations pertaining to land use, forest conservation, national parks and wildlife, mineral resources, water quality control and air quality control. The attempt is made here to review the main aspects of the most relevant regulations.

1) Forest Conservation Legislations:

In Botswana, the Department of Forestry in the Ministry of Agriculture is responsible for regulating the exploitation of forest resources. The Department is under the charge of a chief
conservator of forest responsible for policy making, conservation and management of forest resources. The Department is divided into sections dealing with forest utilisation, protection, production and research.

The legal framework is embodied in the Forestry Act, cap 30 - 04 which has power to declare forest reserves and protect trees.

ii) National Parks and Wildlife Conservation:

The laws and regulations for conservation of national parks are numerous. The most relevant ones are the National Park Act, cap. 30.03 which makes provision for declaring national parks and the Game conservation Act as amended in 1977 which gives powers for declaration of game reserves and sanctuaries. The Department of Wildlife, Ministry of Commerce and Industry is responsible for implementation of the regulations embodied in the acts mentioned.

The legislation that deals with parks and
wildlife specify various ways in which hunting can be regulated in the controlled hunting areas such as prohibition of setting fires to hunt, procurement of licenses to hunt specific game and possession and carrying of firearms.

iii) Mineral Resource Development Legislations:

The laws regulating mineral resources development are specified:

a) Mines and Mineral Act, cap. 66.01 which regulates mining operations and licences

b) Atmospheric pollution (prevention) 65.04 which control air quality during mining operations, discharge of mining waste, water and mining land restoration.

iv) Water Quality Control Legislations:

Water quality is regulated by the Water Affairs Department through its Water Apportionment Board. Technical advice on anti-pollution measures is given to the Board by the senior Water Engineer under
Legislations controlling water pollution include:

c) Water Apportionment Act, Cap. 34.01 which provides for control of water pollution under the Water Apportionment Board which sets standards for quality control for public water, discharge of waste and treatment.

b) Boreholes Act, cap. 34.02 which regulates drilling of boreholes for rural water supply

c) Public Health Act, cap. 63.01 of 1971 controls pollution of drinking water and sanitation regulations.

v) Air quality control

Air pollution problem in Botswana is very serious and is mainly caused by mining activities. Therefore very serious monitoring is done by the Ministry of Mines which has two laboratories for this purpose.
The major acts for air quality control include:

e) Atmospheric Pollution Act, cap. 65.01 regulates air quality and maintains level of pollution.

b) Road Traffic Act, cap. 69.01 regulates vehicle emissions from exhaust gases and engine noise.
1.1.3 Environmental Management in India

In the last few decades, India considered environmental problems from point of view of conserving a few species, particularly animals. The country is now witnessing an increased awareness about the importance of forest as a result of heavy destruction. The country has eroded its capital of forest at a high rate. It is estimated that 23 percent of the India's total area is classified as forestland. Yet, not more than 12 percent of the country's total land is now under adequate tree cover.

Another major problem is that large portion of India's land is degraded as a result of soil erosion. It is mentioned that $\frac{2}{7}$ of the total agricultural and forestlands are highly degraded. About 85 percent of this degradation has been attributed to soil erosion. The sixth five-year plan of India (1980 - 1985) stated that 13 million hectares of agricultural land is subjected to waterlogging, with salinity and alkalinility presenting...
laws and regulations are enforced.

India's environmental priorities are confined to issues of conservation of forests and vegetative cover, the impact of development on the environment and its social and economic dimensions. Bearing these problems in mind India's policy is directed towards implementation of corrective measures such as proper forest management, like tree plantation, wildlife conservation and protection. The country began to foster the ideas of economic planning to incorporate environmental impact assessment as a part of the planning process. These efforts are supported by legal measures that set standards acceptable to the community (table 1).

1.3.1 Protection of the Environment: The case of people's Republic of China:

The environmental protection law in this country is established in accordance with Art. 11 of the constitution of the people's Republic of China. Under this Art.(11), the State entrusted with protection of the environment and natural resources
Table 1: Showing Environmental Issues in India

<table>
<thead>
<tr>
<th>Constraints to Development</th>
<th>Part of Development</th>
<th>Development itself</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Need to conserve forests and special ecosystems</td>
<td>1) More realistic policy framework for socio-economic goals</td>
<td>1) Enhancing tree and vegetation cover</td>
</tr>
<tr>
<td>2) Industrial pollution</td>
<td>2) EIA (Natural environment)</td>
<td>2) Public Health</td>
</tr>
<tr>
<td>3) EIA (Social environment)</td>
<td>3) Community waste disposal</td>
<td>3) Community waste disposal</td>
</tr>
<tr>
<td>4) Population control</td>
<td>4) Human settlement</td>
<td>4) Human settlement</td>
</tr>
<tr>
<td>5) Need for massive investments and availability of technology</td>
<td>5) New energy sources</td>
<td>5) New energy sources</td>
</tr>
<tr>
<td></td>
<td>6) Sound agriculture and water management</td>
<td>6) Sound agriculture and water management</td>
</tr>
</tbody>
</table>

and prevention and elimination of pollution and other hazards to the public.

The function of the environmental protection law in China is to ensure rational use of the natural environment, prevention and elimination of environmental pollution and damage to the ecosystem, in order to create a clean and favourable living and working environment, protect the health of the people, and promote economic development (Art.2).

Art. 5 of the constitution gives the State Council and its subordinate bodies powers to carry out environmental protection work to the highest possible standards. The State Council has established the environmental protection office. The function of this office is stated in Art. 25 of the constitution to be:

1- To implement, and supervise the implementation, and national guidelines, policies, laws and acts relating to environmental protection;
2- To draft regulations, rules, standards, economic and technical policies relating
to environmental protection in conjunction with the relevant departments.

3- To make long-term programmes and yearly plans for the protection of the environment and supervise its implementation.

4- To make unified plans for organizing the monitoring of the environment, carry out investigations and keep under view the situation and trends of the whole country.

5- To organize and co-ordinate research and educational programme in environmental sciences.

6- To direct the environmental protection work of all units directly under the central government.

7- To organize and co-ordinate international cooperation and communication in the field of environmental protection.

The departments under the state council and the local people's government and relevant institutions are authorized to establish environmental
protection offices separately responsible for the protection of the environment within their system of affiliated organisations, departments and units (Art. 28)

1.3.5 Environmental Quality in U.S.A.: Improving the quality of the environmental has been the objective of a number of laws passed by the Congress and executive orders issued by President in the last few decades. However, the National Environmental policy Act (NEPA) of 1969 is the only law that provides for a long-term holistic approach to deal with environmental problems and advise the President on how to tackle some of the environmental problems of the future.

The NEPA requires that all development activities must be environmentally assessed before implementation. The environmental assessment must include:

i) The environmental impact of the proposed actions;

ii) Any adverse environmental effects which can not
be avoided should the proposed action be implemented;

iii) Alternatives to the proposed actions;

iv) The relationship between local short-term uses of man’s environment and maintenance and enhancement of long-term productivity;

v) Any irreversible commitments of the resources which should be involved in the proposed actions should it be implemented.

The National Environmental Policy Act of 1969 provided for the establishment in the executive office of the President a three member council on environmental quality called Council on Environmental Quality. The general purpose of the Council is to assist the President with respect to environmental quality matters. One of its specific duties is to review the adequacy of existing systems for monitoring and predicting environmental changes. The Council was specifically given the duty "to develop and recommend to the President national policies to enhance and promote the improvement of environmental quality to meet the conservation, social, economic,
Health and other requirements and goals of the nation

Other duties of the Environmental Quality council is to assist and advise the President in preparation of an annual Environmental Quality Report. This report outlines achievements and policies with regard to current and foreseeable trends in quality, management and utilization of the environmental resources and the requirements of the nation.
2.1 General

The Sudan, the largest tropical country in Africa, covers an area of about 2.5 million km², between latitudes 15° and 33°N. Accordingly, it enjoys great diversity in topography, soils, climate, flora, fauna and cultural diversity. Thus, this mosaic results in a vast and varied natural resource base. Yet, the Sudan can be described either in terms of great wealth and enormous potentials or as a country of unused resources (J. Berry, 1983).

The land and water provide the principal natural resources in the country. The Nile has irrigated over four million acres of land, exploited for generating a substantial portion of hydroelectric power, used for navigation and provides significant sources of protein.

The land, the foremost important natural resource in the Sudan, is only exploited to a limited extent. It is estimated that out of 600 million acres; 200 million acres or 10% of the available...
land is under cultivation presently. Even though, it is being rapidly transformed and degraded without much knowledge of the consequences and without co-ordination and proper planning (FAO, 1983).

The woodland resource covers about 22.3% of the total area of the country (Beyene, 1981). Yet, only 3% of the total woodland is kept in reserve and no complete inventory for natural forest resource had been undertaken. This valuable resource has been suffering from growing demand of wood for construction and fuel and is threatened by agricultural expansion.

The natural rangeland is estimated by Range and Pasture Administration to be over 61% of the total area. Supporting about 50 million head of domestic animals, yet, it is regarded by most as a fixed rather than a disposable wealth. However, it can offer a considerable scope for development if properly managed. In addition, the country is enjoying an unusually rich wildlife resource, occupying the different vegetational zones. This being for centuries an important source of protein and other animal
products. It has also greater long-term value as an important and irreplaceable part of both national and international heritage. Yet, many species of wildlife become endangered due to change in natural habitat, combined with uncontrolled hunting.

Although, the exploration and mining of mineral resources have low share of funds in development plans, but, it is expected to play a vital part in the Sudan's economy in the near future. Important minerals such as chrome, copper, lead, etc. are being prospected. Oils have been discovered in the south west region and it is hoped that petroleum will be exploited commercially.

All these resources if utilized properly, taking into consideration conservation and management aspects, will benefit the present and future generations. This will lead to increase in production, raising per capita income and bringing the welfare to the population at large.

2.2 The Problem

The government policy had been aimed to attain the
living standard of the developed nations. To achieve such a goal it accelerated the use of natural resources. But, this is done with the following defects:

1) Complete negligence of environmental issues in development plans;
2) Lack of integrated multi-sectoral planning and management approach; and
3) The absence of co-ordinating institutional structure to tackle all development and management problems.

In the presence of these obstacles the ultimate results have been mismanagement of natural resources and severe degradation of the environment. This manifested itself in desertification, decline in yields, water-borne diseases, frequent dust storms as a result of removal of vegetation cover and suffering of the people in form of famines as in Darfur and Kordofan and large scale rural emigration.

2.3 Objectives:

Bearing in mind the problems discussed in the previous section, this study tries:
1) To assess the role of different departments, agencies and corporations with respect to resource management and protection.

2) To evaluate the adequacy of the different laws and regulations and existing institutions responsible for environmental conservation.

3) To survey and study the Gedarof region as a case study to reflect the approaches followed in resource management and mismanagement.

4) The study also aims at recommending and suggesting new structures and organizations to achieve co-ordination among the different units involved in natural resource management.

2.4. Hypothesis

In order to achieve the objectives of this survey the following hypothesis are put forward for testing:

1) For the country as a whole there is no clear environmental policy and clear national objectives.

2) Each department plans and implements its
Environmental policies without co-ordinating with other units.

3) Environmental aspects are not considered in development plans.

4) Bad management practices adopted by the farmers in the mechanized scheme resulted in soil degradation and declining productivity.

5) As a result of 1, 2, 3 and 4 environmental mismanagement resulted in resource degradation and desertification as reflected in the Gederef district.

2.5 Material and Methods of Data Collection:

Different approaches were followed for data collection including the following:

2.5.1 Documentary Sources:

These include reports and files discussing development plans, environmental laws and regulations, policies and national or regional acts dealing with the environment. In fact these sources were found to be very useful in explaining the institutional
framework, national priorities and environmental concern at the national and regional level.

2.5.2 Fieldwork and Interviews:

Field data collection was undertaken during November 1983 to March 1984 at the Gedaref region. Data was collected through observation, analysis of soil samples and interviews.

1) Site Selection:

For simplicity and convenience the Gedaref region was divided into two parts:

1) The northern part where the mechanised rainfed farming was first introduced, and

2) The southern part which is relatively newly developed and opened for rainfed mechanised agriculture.

After a thorough survey, three water centres were selected from each section in such a way as to represent the whole area. The selection being according to random sampling techniques. These centres are:
1) Omdurman town, Chademabeliya and Um Shahra in the northern part.

2) Sasseen, Doka and Shuheit village in the Southern part.

ii) Questionnaires:

Two types of questionnaires were prepared to deal with management problems at the decision-makers (planners) level and at the farm level. The former questionnaire (Appendix 2/1) was designed with open-ended questions and centered around policies, laws and regulations, co-ordination, activities or projects and problems facing each department with respect to environmental and natural resource issues. The second questionnaire (Appendix 2/2) was designed with close-ended questions. The aim was to get information from farmers to know their perception towards the changes in the environmental conditions in the area as a result of mechanization. Thus the questions covered the following areas of study:

1) Information about the respondent.

2) Field management and cultural practices.
3) Perception towards the changes in vegetation, soils and yields.

4) Recommendations and guidelines about farming, conservation and management.

5) Livestock feeding and energy sources.

The answers were tabulated, given code numbers and then the percentages were calculated. The size sample being 160 farmers randomly selected out of 2400 farmers.

111) Soil Sampling and Analysis

Soil samples have been taken with the aim of representing all soil classes in the region and to enable the assessment of the effect of mechanical farming on the soil.

The first type of samples were taken from a controlled fallow land not cultivated at least for five years. The second type of samples were taken from fields which are relatively newly cultivated for periods lasting from four to ten years. The third sort of samples were taken from fields which are continuously
under cultivation for the last forty years. Out of these substrate soil sampling was done.

The soil samples were taken from the plough layer (from 0 to 30 cm) using a soil auger.

Each sample was analysed mechanically and chemically. The mechanical analysis was carried to determine the percentage of sand, silt and clay in each sample. Chemical analysis being for organic carbon (O.C.), available nitrogen, pH, exchangeable Na and K, soluble cations and anions, electrical conductivity (E.C) and cation exchange capacity (C.E.C). This soil analysis is very important indicator of physical desertification.

The methods used for chemical and physical analysis were the standard methods used at the Laboratories of Soil Survey Administration at Wadi Medani, as described by Syd. Abdel Korim El Obeid (1973), and Syd. Johan Tange (1973). A brief summary of the method is given below.

1) pH is determined by glass/calomel electrode
(mmol, kcl) system.


Exchangeable Na and K: Na and K are extracted with IN ammonium acetate (pH: 7) and determined by flame photometer. Exchangeable K is equal to thus extracted K, as water soluble K is negligible. Exchangeable Na is equal to thus extracted Na minus soluble Na.

5) Soluble cations and anions: water soluble sodium is determined by flame photometer. Ca\(^{++}\), Mg\(^{++}\), carbonate (CO\(_3\)^{--}\), bicarbonate (HCO\(_3\)^{--}\) and chloride (Cl\(^{-}\)) are determined by titration.

6) Available phosphorous: is determined by using Olsen's sodium bicarbonate method.

7) Electrical conductivity (E.C): saturation paste is prepared by adding soil to known quantity of water to the paste consistency. Saturation extract is sucked off using vacuum, E.C. of saturation extract is read off a conductometer and expressed in mhos per cm at 25°C.
8) Cation exchange capacity (C.E.C): is determined by leaching in sodium acetate (pH: 9.2) washing with ethanol and extraction of the exchanged sodium ions with ammonium acetate (pH: 7.0). Sodium is then determined by flame photometer.

9) Chemical analysis: for mechanical analysis the hydrometer method was used. Samples broken up, oven dried and sieved through 2 mm sieve. Fine soil is pretreated with HCl, washed and dispersed with colgin (sodium hexametaphosphate). Pipette method for silt and clay, and wet sieving for coarse and fine sand.

iv) Soil Resistance to Penetration:

Soil testing was carried out to see the effect that may arise from using the common fillage practices. A USL soil test, hand operated, Inc. penetrometer with providing ring (PR - 025), serial number (S/N, 10863) and 250 pound loading capacity, was used for testing the soil strength.

A calibrated curve (Fig. 5) was established
FIG 51  PENETROMETER CALIBRATION CURVE (PROVIDING RING NO.10865)

SCALE:
- X Axis = 110
- Y Axis = 1.50 x 10^5

1 lb/in² = 0.07 kg/cm²

DIAL READING IN 10^-4

LOAD IN POUND
for the conversion of the penetrometer dial reading into stress form (kg/cm²).

The soil resistance to penetration was recorded at one depth and then at one inch increments until it was impossible to drive the penetrometer steadily further down. Three stations were randomly selected and soil strength readings were taken. Stations (1) representing a controlled area that was not subjected to any kind of ploughing (forest). Station (2) representing areas that were subjected to continuous shallow ploughing using the conventional wide level disc (2.5 ft). Station (3) representing areas that were deep ploughed using chisel plough and other secondary tillage.

2.5.3 Data Analysis:

One of the indicators of soil degradation and hence desertification is believed to be drop in yields per feddan. Drop in yields in the district during the last years was examined. Certain consideration was given to the interrelation between variables that may affect yield. The variables which were examined
are the total area and the total annual rainfall. A table containing numerical values of the three variables (yields, total area and total annual rainfall) was extracted from the annual reports of the Mechanized Farming Corporation (M.F.C) for the period 1954 - 1983. Thirty observations were assigned at random $X_1$, $X_2$ and $X_3$. The regression model was fed into the computer (University of Khartoum Unit) for print out.
CHAPTER II
Environmental Management in The Sudan

3.1 Historical Background:

Natural resources depletion and deterioration prompted the idea of conservation in the Sudan. In 1962 - 1964 the Soil Conservation Committee (SCC) reported on the position of soil, rural water and other related problems. This committee finished its report on the promotion and utilization of natural resources, village planning and the effect of promotion of rural water on keeping law and order.

In 1966 - 1956 the soil conservation section was established to take up the implementation of the recommendations of the SCC. Within the scope of this section was the provision of surface water for animals in grazing areas to lessen overgrazing and reduce the efforts of nomads in search for water.

In 1956-1966 Landuse and Rural Water Development was created under the supervision of the Ministry of Agriculture. The main task of this department was to coordinate the work of the executive units of
water supply and of those units, responsible for planning of landuse.

During the period from 1966 to 1969 an anti-thirst campaign was implemented. As a result, the government launched an extensive water supply programme in the different parts of the country. The new sites were not studied from landuse point of view, in particular the carrying capacity of the land resources and the pattern of nomadic movement. The result was severe overgrazing and soil deterioration.

In 1976 Sudan's Desert Encroachment, Control and Rehabilitation Programme (D.E.C.R.P.) was created to deal with the problems of desertification control. The D.E.C.R.P. is based primarily on the assumption that desert encroachment is a consequence of man's activities and that voluntary participation of landusers is required for its control.

In 1983 the State Minister for Agriculture declared that "natural resources conservation and
protection from deterioration is a national responsibility. And in the effort to improve the agricultural sector we must revise our land use practices in order to stop irrational exploitation and ensure a balanced environment.

In spite of the several statements on the natural resources and the environmental management, there is nothing yet in existence which could be called a coherent policy on environmental management in the Sudan. Yet, there is a very high level of general agreement among those involved in the development process that the environmental management is a priority.

3.2 National environmental objectives:

In the Sudan, the 1973 constitution makes no specific reference to environmental policy, but it provides a general remark concerning the "Natural wealth and resources under or above the ground or within the territorial waters, will be the property of the State, and the State shall secure appropriate exploitation". (Art. 37).
The interpretation of the concept of appropriate exploitation may be found in the last Six-Year Development Plan (1971-1982). This plan aims at attaining "balanced growth in the country's economy through conservation of natural resources". The plan did not specify the meaning of conservation but it may be taken to mean the rational use of resources.

The plan, in order to achieve its objectives, aims at both "vertical" and "horizontal" expansion of agricultural production through expansion in the areas under mechanized farming and traditional agriculture and by intensive application of fertilizers and pesticides. All these activities are expected to have negative environmental effects because the development activities taking place in the country are not environmentally assessed. Projects are only economically evaluated without further investigating their environmental impacts.

3.3 Environmental and Resource Management in Development Plans:

An attempt is made here to review the main
elements of the different development plans executed in the country to see the place of environmental considerations in these plans. The Ten-Year Plan, (1964/1965- 1970/1971) is the first post-Independence plan with clearly defined objectives. The main objectives of the plan revolve around improving the economic base and broadening the structure of the Sudanese economy through agricultural expansion to increase the level of exports.

The objectives of the plan were criticised as being "neither detailed nor comprehensive, nor do they comprise a clear set of quantitative targets" (Suleiman, 1975). The most serious defect of the plan with major negative environmental impact is the expansion in the agricultural sector, especially irrigated agriculture without proper environmental considerations and assessments.

The Five-Year Development plan (1970/1971-1974/1975) also gives top priority to agriculture. A major share (30.1%) of the total plan resources was allocated to this sector with the aim of increasing
agricultural production by 75.5%. The plan as its predecessor ignored the issue of natural resources protection. The Six-Year plan (1977/1978 – 1982/1983) followed the same pattern. Principally the plan aims at achieving an accelerated and balanced growth in the Sudanese economy combining development with equity, with agriculture continuing to be the pivot of development and leading sector of the economy.

As stated earlier, one of the methods for achieving the accelerated balanced growth, is the conservation of natural resources. Yet, the natural resources sub-sector in the plan was given low share of investments. A total of 5.8 375 million was originally allocated for implementation of some 27 projects detailed in table (2).
Table (2): Natural Resources Sector, Projects Proposed and costs for the Six-Year Plan.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Number of Projects</th>
<th>Costs L.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forestry</td>
<td>11</td>
<td>9 millions</td>
</tr>
<tr>
<td>Wildlife</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Range and Pastures</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Soil Conservation</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27</strong></td>
<td><strong>37</strong></td>
</tr>
</tbody>
</table>


These projects and the activities proposed include: tree planting, soil conservation, desertification control and increase in forest resources. However, the approved financial support for the implementation of these projects is far below the proposed and the estimated costs. A mission sent
by FAO in 1980 concluded that the projects proposed by the different departments involved in natural resources protection faces serious difficulties because of the limited resources, while more resources were given to mechanized and irrigated agriculture leading to environmental degradation.

3.4 Role of Government Institutions Responsible for Environmental and Natural Resources Management:

The main purpose of this section is to highlight the main activities of the ministries involved in environmental and natural resources management. The most important ministries include: Agriculture, Health, Mining and Energy, etc.

3.4.1. Ministry of Agriculture and Irrigation:

By far this ministry contributes a great deal to the efforts regarding environmental protection as well as to the degradation taking place. This ministry incorporates most of the departments involved in natural resources utilization. As the administrative structure and capabilities of the departments plays important role in the management of the
natural resources, an attempt is made here to direct attention to the activities of these departments in the field of environmental management.

3.4.1.1 Soil Conservation, Landuse and Water Programming Administration:

As its name indicates, the Administration's main activities are:

1- To plan for water supply to rural areas within the framework of rational utilization and protection of natural resources;

2- To carry out landuse studies and prepare landuse plans for the Sudan; and

3- Initiate rural development programmes by establishing pilot projects in rural areas.

In order to carry out these objectives the Administration is divided into the following sections:

1) Water use section;
2) Pilot projects section;
3) Lab section;
4) Social Affairs section;
5) Remote sensing section; and
6) Planning and follow-up section.

Efforts are made by the different sections to programme rural water supplies in accordance with land capabilities and population and animal pressure. Also, the department tried to formulate a land use policy and a draft was suggested early in the 1960's, but was not approved. Thus, till this date there is no land use policy for the country as a whole. This resulted in unco-ordinated and fragmented activities with serious consequences on cover removal and land degradation. Lack of a clear land use policy coupled with political pressure especially in the field of rural water supplies, compelled the department to abandon the criteria established for water provision which take into consideration land capabilities and rational land use policies.

Since the early attempt made in the early 1960's, nothing concerning land use policy has been stated. Currently, there is no institution which is responsible for making co-ordinated land use decisions. The urgent need for a definitive land use...
planning policy cannot be overemphasised. Stating that all land in the Sudan of any kind is the property of the government should not be itself considered a solution to the land problem. This is because State ownership does not place the land under identifiable administration or corporation so as to determine the priorities of use on a given piece of land or to be blamed for the misuse that happens.

Secondly, there is no government policy for the use of "Government" land except by reference to the Six-Year Plan, where each unit has generally found approval for its landuse proposals. Even when they conflict there is no standard by which different uses can be harmonised. The result more land is being transformed without much knowledge of the consequences and without co-ordination or proper planning as a PLO 1979 report stated that "The current trends will exacerbate grazing and forestry supply problems and compromise wildlife populations" p. 22.

39.1.2 The Forest Administration

The Forest Department forms an important
department in the Ministry of Agriculture charged with the responsibilities of making the country self-sufficient from forest products in a constant and continuous way and to ensure effective utilization of forest resources. The strategy of the Administration to achieve these objectives as outlined in the Six-Year Plan is as follows:

1) Conservation and protection of forests.
2) Establish tree plantation and afforestation projects to increase the production of wood.
3) Establish industries based on forestry raw materials.

The Six-Year Plan provides for forestry projects in the public sector, costing of 1.6 3.4 millions and also aims at expanding the reserved forest area from 3.1 million feddans to 5.0 million feddans. The production of sawn timber is to be increased by the rehabilitation and expansion of sawmills. There are also projects for extraction of more round timber and poles, planting shelter belts for desert creep. In general, the forestry programme in the Six
Year plan was criticized by J.W. Barrette 1978 as lacking elements of careful planning.

Some of the obstacles facing this administration are the absence of forest inventory for the Sudan, and for most parts data concerning forest resources is only rough estimates. Forest land in the Sudan is estimated to cover about 22.9% of the total area of Sudan ranging from savanna woodland in the north to gallery forests in the mountains and southern Sudan.

Yet this valuable resource is not utilized effectively. While provinces of central Sudan suffer from annual take-off far beyond sustainable yields, the Southern Provinces enjoy a forestry surplus. Also, the distribution of forest resources and population are not compatible with rational use of resources. The southern Sudan has some 57% of the forests in the country but only 27% of the total population, while the northern Sudan has 43% of the forests but 73% of the total population.

Forest utilization and protection faces many problems represented by
1. Lack of landuse policy and the inability of forest to compete with agriculture as an economic activity that generates foreign currency. Some authorities attribute this competitive weakness to the failure of the Forestry Administration to analyze costs and benefits, and present the results in aggressive manner (FAC, 1979). In fact, experience throughout the World has shown that Agriculture and forestry landuse must work in harmony, with long-term view of both sectors.

The horizontal expansion of mechanized farming has led to a large scale clearance of forest resources. Forestry guidelines for mechanized rainfed schemes requiring that slopes and other fragile lands to remain forested, requiring a minimum percentage to be left in shelter belts, etc have been ignored by the mechanized farmers.

2. The second problem arose as a result of the formation of regional government in the Sudan. As a result of this regionalization many powers of the central ministries were given to the regions. Thus,
the Forest Administration was decentralized and a major share of its powers were given to the regions and provinces. Now, the provinces have full jurisdiction over the forests under their control while the central Forest Administration supplies them with trained personnel.

The most shortcoming of this development is that provinces do not seem to be concerned with their role as forest supplier to the whole country. Thus, very little is being spent on forestry. Sometimes even the running costs of vital operations are not available. Also, as a result of decentralization the central Administration lost the power to influence the provinces to follow a rational forest policy.

3.4.1.3 Range and Pasture Administration

The Administration's major responsibilities are to ensure rational use of grazing resources, conservation, improvement and management of the rangelands. To achieve these, the Administration tries to
1. Conduct research by technical staff in order to carry out rehabilitation of lost pastures;
2. Prevent the spread of uncontrolled fires; and
3. Building pasture enclosures to protect valuable rangelands and pasture.

The Administration's policy in the Six-Year plan, involves the interpretation of livestock management and crop cultivation and to experiment with the planting of legumes which would be suitable for fattening livestock. Also, to establish co-operative ranches where farmers will be encouraged to contribute livestock. Yet, no success has been reported.

The main problems facing the Administration include:

1. The absence of clear government policy in respect to grazing rights. This is because of the absence of landuse policy. In such circumstances, the customary law and traditional grazing rights provide the main framework for range management. But the open grazing presents a major problem in respect to management and rational use.
2- Horizontal expansion of mechanized reinfed farming deprived traditional range users from large areas with high grazing potential.

3- Increase of animal population resulted in the disturbance of the natural ecological equilibrium between animals and their feed resources. (See table No. 3). The 1979 animal census shows that animal numbers are far beyond the carrying capacity. The surplus is estimated to be 5.3 million animal units. All these contributed to the severe overgrazing and tribal conflicts.

The overgrazing problem is closely linked to the government's policy with respect to provision of water during the period from 1966 to 1969 "anti-thirst campaign". During this period a large number of boreholes were drilled without proper landuse studies to assess the carrying capacity and land potentials.

4- Range fires which were estimated to consume annually about 35% of the natural range productivity and contribute to the change in plant composition
<table>
<thead>
<tr>
<th>Source</th>
<th>Income and Expense Computation (1991)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>8.00</td>
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<tr>
<td></td>
<td>12.00</td>
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<td></td>
<td>24.00</td>
</tr>
<tr>
<td></td>
<td>48.00</td>
</tr>
<tr>
<td></td>
<td>72.00</td>
</tr>
</tbody>
</table>

Legend:
- Budget
- Revenue
- Expenses
- Total

Note: Actual income and expenses shown in this section.
and expose soil to erosion. Thus, the Administration devotes much efforts in making firelines and establishing range reserves.

3.4.1.4 Wildlife Administration

This Administration was originally conceived as a licensing and policy-making body and later on its mandate was extended to include protection, conservation and management of wildlife habitat. In 1981 the Administration was declared as a regular force called "Wildlife Conservation Forces" in the Ministry of Interior.

The Administration is entrusted with the management of wildlife, national parks and enforcement and implementation of Wild Animal Ordinance (1935).

According to the Wild Animal Ordinance, hunting is prohibited in national parks, but it is permitted in game reserves if a special permit is given by the Director of Wildlife Administration. Conservation in these "protected areas" is unsatisfactory. According to Midir and Roblin (1970), some of the game
reserves are no longer worth of their name. In the southern region alone there are two national parks and 15 game reserves, but none of them have been fully demarcated. There are no adequate maps or any of these areas, no survey or other investigations necessary to produce basic data for planning and management (Ma c, 1977). The only national park in the north- Binder National Park is described as a non complete ecological unit, for many species of animals migrate to yet season range outside the boundaries of the park.

The Administration's lack of trained personnel, adequate means of transportation and necessary equipments make any attempt at protection or surveying impossible. It seems that the major emphasis of the Administration's activities is exploitation rather than conservation. It was reported that in **recent past years, there has been regrettable poach- ing operations. It is clear that there is little appreciation of the value of wildlife in the country and it is regarded by most as nothing more than
Inexhaustible source of free meat. This unconscionable attitude together with vast expansion of the protected areas make the control a very difficult job.

Other major problems in addition to poaching and inadequate facilities, is the serious landscape conflict. This is clearly felt in the Binder National Park. Here horizontal expansion of mechanized farming; both licensed and unlicensed have taken considerable portion of the park area that used to be wet season habitat for wildlife. Also, the increase of cultivated areas in Binder region is pushing the nomads from their traditional dry season ranges. As, they are forced to invade the wildlife range and compete with wildlife for forage and water. Mixir 1984, estimated that the number of trespassing by livestock has increased by 125 folds during the period from 1970 to 1982. Also, reported that livestock could be a source of infections disease to wild animals and that hundreds of wild animals had been lost as a result of rinderpest outbreaks. Adding to these conflicts, the indiscriminate cutting of
wood by settlers for firewood and charcoal making have serious effects on changing the park habitat.

3.4.1.5 National Desertification Control, Co-ordination and Monitoring Unit (D.E.C.C.R.F.)

This Unit is conceived as a coordinating body entrusted to streamline activities designed to control desertification and to seek funds for their implementation. The Unit's major activities are:

1) to review the project proposal prepared by D.E.C.C.R.F. for submission to external aid and to follow up on going projects;

2) Survey, monitoring and mapping of desertified areas;

3) to organise training, enlightenment and extension campaign in regions affected by desertification.

In spite of the importance of the desertification problem both nationally and regionally, yet only three projects out of those proposed by D.E.C.C.R.F. have been financed, namely:

1) Restocking of Ou Adda Belt in Northern
2) Grazing Management around permanent water supply in El-Odina - Kordofan - and
3) Strengthening the National Desertification Unit.

The major problem facing the Unit is the limited budget allocation both local and foreign. Secondly, there is a considerable overlap between the Unit's work and the other administrations involved in natural resources management.

3.4.2 Ministry of Irrigation:

The Ministry of Irrigation used to be a separate ministry but since 1991 it became part of the Ministry of Agriculture. The main functions of this Ministry include:

1) Utilization of Sudan's share of the Nile waters.
2) Water resources research.
3) Design, planning, construction, operation and maintenance of irrigation structures.
It seems that the important task is the control, utilization and the development of the country's resources. In this aspect there are other units and agencies which are not part of this Ministry taking active part in water provision or utilization, thus, emerges the problem of co-ordination.

3.4.3 The National Committee for Environment:

The National Committee for Environment of the National Council for Research (N.C.R.) provides the only example found in the Sudan to co-ordinate the environmental activities. In 1977 the council (N.C.R.) created the National Committee to carry out the following functions:

1) Preparation, together with the national institutions and experts, of the studies related to the environmental affairs problems.

2) Studying of the environmental impacts of the development projects to rationalize the natural resource utilization and coordination between the different units involved in the country's
3) Activation of formation of regional committees around the country to deal with the environment.

4) Activation of concerned departments to enact and develop laws for the protection of the environment.

5) Provide the guidance for the formation and activation of the executive committee for environmental protection.

6) Improving environmental awareness among the people.

7) Studying and coordination of the country's needs in the field of the environment from the UN Organisations specially UNEP or through the bilateral or multi-lateral treaties.

8) Act for Sudan's participation in the environmental activities held by the UN and other regional, national, governmental or non-governmental organisations.
9) Look after UNEP activities and decision for their implementation in the Sudan.

When the committee was established it was hoped that it will provide a sound basis for coordinating activities of environmental concerns and link these with UNEP's activities. But, many shortcomings hinder the committee from carrying out these activities including lack of trained personnel and shortage of funds.

There are other governmental agencies responsible for administration and management of the environment and natural resources in the Sudan including Ministries of Health, Industry, Energy and Mining, National Planning and Education.

The above discussion indicated clearly the piecemeal approach to environmental management, the overlapping responsibilities and lack of coordination between the different government departments.

In order to reduce these drawbacks the government is proposing the formulation of a Superzone
Council for Natural Resources. The main functions of this council is discussed here.

3.4.4. The Supreme Council for Natural Resources:

In an attempt to coordinate the activities of the different government agencies involved in natural resources management, the Ministry of Agriculture proposed the creation of a "Supreme Council for Natural Resources". The objectives of the proposed council involves the following:

1) Revising, rectifying and setting up of the national policies pertaining to development, conservation, and management of natural resources in an integrated and balanced manner; to ensure sustained and continuous productivity of these resources and protect them from deterioration.

2) Coordination of the different efforts aiming at protection of renewable natural resources, setting of priorities and to carry out inter-related surveys and studies of these resources,
determining their present status, monitoring any change that might take place and defining the fragile areas.

3) Defining and allocation of land and water resources for multi-use purposes according to their capabilities taking into consideration the national, regional and local needs.

4) Device long-term plans to achieve rational use of the renewable natural resources.

5/A To carry out periodical revision on the efficiency of the existing natural resource legislations and forwarding recommendations for amendment, or setting of new ones so as to achieve the goals and the policies act and follow up their implementation.

6) Establishment of unified comprehensive laws for environmental management.

7) Create public awareness and attitude towards the rational exploitation and conservation of the natural resources and to be incorporated in the curriculum at all levels of education.
In my opinion this Council is the first step to compomise the different government units. Also, the Council can be promoted further on to include the environment as a whole and to be a nucleus for a comprehensive structure for environmental administration as found in many developed countries (e.g. Department of the Environment in the United Kingdom and the Ministry of Nature and the Environment in France).
1.5 Environmental Laws and Regulations

In the previous sections brief comments were made on the activities of some governmental departments. In the following section an attempt will be made to review some of the environmental acts that give power to the concerned departments to achieve their goals in natural resource protection. In this review special attention will be given to the discussion of the obstacles for the implementation of these acts and to assess the inadequacies of these regulations.

As mentioned earlier, there are a number of acts, regulations and laws covering the main elements of the environment. These include: fisheries, forests, wildlife, public health acts,...

1.5.1 Health-

The 1973 constitution provides that: "Public health care and medication is a right for each citizen and the State shall arrange for its free delivery" (Art. 54). In accordance with this provision the public Health Act of 1975 and the Environmental
Health Act of 1975 were issued.

The Environmental Health Act of 1975 is the only act that deals with the quality of the environment. With the exception of chapter I the rest of the Act deals with the institutional responsibilities for water and air pollution. The Act imposes a duty on the local councils to protect the health of human beings, animals and plants, through the following measures: town and village planning according to health regulations, proper drainage, sewage and garbage disposal and planting of trees to stop air pollution. The whole of chapter III deals with the prevention of water pollution. It aims at preventing the addition of any solids, fluids, industrial wastes, chemicals, sewage, refuse and remains of animals to water supply sources or inside rivers, canals, wells, natural ponds or into the sea to avoid causing harm to the health of man and animals. The Act also specifies the conditions of storage and supply of water and ban its supply before analysing it by the appropriate technical authorities to ensure
its freedom from pollution. Protective measures are provided against spread of epidemic diseases by water supply sources and regulates the disposal of sewage and industrial wastes in water courses.

The Act imposes considerable obligations on people's councils to issue regulations or instructions for the implementation of their duties without much guidelines, only to act upon the Ministry of Health and the Public Health Board. The Public Health Act of 1975 describes the function of the Board (Section 5) as establishment of environmental health standards (sec 5/1) and propose plans and general policy of health affairs on the country level (sec 5/2).

These two Acts are considered as the first step for the promotion of environmental health, but their enforcement is not feasible within the prevailing economic situation of the country. Secondly, the lack of trained personnel at the local level and the inadequacy of health education makes the implementation of these Acts a difficult if not an impossible task.
3.5.2 Water Resource Laws:

Although water is an indivisible resource, yet it is planned and administered by numerous government agencies. This resulted in overlap and confusion of responsibilities and hence in mixing and legal contradiction. Also, the legislations break up this resource into different management sectors. Today there are 14 legislative texts (appendix I) dealing with water supply, use and quality. Despite the abundance of the laws, yet there is no definitive declaration of water quality criteria. Also apart from the Environmental Health Act, there is no legislation to regulate water resources other than the Nile.

Realizing the danger of this situation, the government drafted a proposal for the Water Act and now waiting for approval. This Act is "to make better provision for the conservation, control, appointment and use of the water resources of the Sudan, and for purposes incidental thereto and connected therewith."
The proposed Water Act covers the following:

1) Ownership and control of water.
2) Water Resources Authority (W.R.A.).
3) Local Planning.
4) Water appointment board.
5) Water permits.
6) Dams.
7) Abstraction of ground water and permit therefore.

8) Variation and collection of permit.

The Act applies to all water resources, to irrigation, urban supply, ground water and to pollution control, etc. It emphasizes that all water in the Sudan should be exercised by the Minister.

According to this provision of the proposed Act, there will be established a National Water Resources Council comprising all national government’s ministries whose functions impinge on water resources. The council will be the only form on which the Minister may rely for advice in formulating policies and resistance in developing necessary plans.
3.5.3 Land Tenure and Land Use Planning:

Land tenure is governed by both written and customary laws. Land tenure arrangements are governed by the "Land Settlement and Registration Ordinance of 1925, accordingly" all unregistered land is deemed to be the property of the government until the contrary is proved. This government's ownership of land falls into three distinct categories:

1) Government land subject to no right;

2) Government land - unsettled and unregistered subject to right (vested) in a community, such as a tribe, section, or village or sometimes individuals;

3) Government land - settled and registered but leased for government agencies, individuals or co-operatives.

Also, reference to land is found in unregistered land Act of 1970, "all land in Solomon of any Kind whatsoever, whether, forests, occupied or unoccupied deemed to be the property of the government unless
it is subject to use or enjoyment by private person for a long time, before it is registered in the name of the government according to unregistered land Act of 1970. So, people have right of use to the land in many ways:

1) Through inheritance.
2) Through long-term residence or use.
3) Lease.
4) The right of pre-emption.

There is no specific legislation dealing with the land use, but there are different laws organizing right to land depending upon type of land use, for example:

1) Home Tax Act, 1928
2) Gezira Deltamont Act, 1928
3) Gezira Land Act, 1927
4) Nile Fung Control Act, 1929
5) Water Deits (Tenancy protection) Act, 1943.
6) Taxation of Realland (Wahur) Act, 1924
7) Taxation of Land and Dote Fesaa Act, 1925
8) Central Forest Act, 1932
9) Provincial Forest Act, 1932.

Yet, only the Mechanized Farming regulation contained reforms to landuse considerations, "a complete for the proper exploitation of natural resources and within the framework which consolidate production and attainment of stability" for the planned areas, regulation 7 (c).

3.5.4. Forestry Legislations:

There are two major forestry acts, namely, the central Forest Act of 1932 and the provincial Forest Act of 1932. Yet, there are several other acts which directly or indirectly affects forestry, for example: Land settlement and Registration Act of 1925 which provides for the registration of ownership and other right in land, including right of pasture, "forest produce" and cultivation occupation; the Unregistered land Act of 1970; Agricultural Tenancies Legislation ... etc...

Both the major Forest Acts dated back to the
colonial period and they are not relevant with need for multi-purpose forestry. The process of decentralization somewhat displaced them, and a draft is waiting to be passed as a bill to replace them.

Another shortcoming of the 1932 Acts and resultant forest policies is its inability to cope with the developments that took place particularly in the field of mechanized farming and the recent decentralization.

The draft forest Act is hoped to be an advance stage and find solution to the shortcomings associated with the 1932 Acts. It provides for a more comprehensive policy in the light of decentralization and its consequences and has the advantage of directing greater attention to non-reserved land i.e., less reserve oriented policy. Also, it changes the purpose of reserves to be more flexible to include in addition to production, protection, recreation, greening and farming taking into account this will not affect its role in production and protection (R.L, 1979).
3.5.5 Game Ordinance and Regulations:

The Wild Animal Ordinance of 1935, as amended in 1971, is the basic legislation under which the Wildlife Conservation Force operates. It also regulates the management of national parks and sanctuaries.

These regulations classify the wild animals into schedules: totally protected, species to be hunted by special license, and species that can be hunted by ordinary license.

The basic legislative text was subjected to many amendments. The Wild Animal Ordinance, 1935, was amended in 1971; the Game Regulations was amended in 1961; and the National Park Sanctuaries, Reserves Regulations of 1939 was amended in 1985. So, the basic act lost much of its original clarity. In spite of all the amendments, made still, they are not exhaustive, for example no regulations exists for implementation of CITES "Convention for Regulation of Trade in Endangered Species". Also, the law does not make a definition statement and national park policy.
In 1973 at the request of the government, a FAO, legal consultant was sent to Sudan to assist the government in formulating a new comprehensive Wildlife and National Parks, but this has formally passed.

3.5.6. Fisheries and Marine Resources Legislation:

The legislative instruments for development of fisheries resources in the Sudan include the Marine Fisheries Act of 1937 and the Fresh Water Act of 1954. The former includes in addition to the definition of "fishing" and marine products, the prohibition of fishing in territorial waters and certain declared areas for the sake of conservation, authorizing the local administration to restrict fishing in certain seasons, determine size of marine products to be taken and prohibit any means which hinder the development of fisheries. The Fresh Water Act of 1954 prohibits any using of indiscriminate means of fishing and specify conditions under which license for fishing to be issued. Also the Act empowered the Minister to make regulations to prescribe type and size of nets, size of
mesh, and to declare the closed season for fishing.

Both acts are out of date and they do not take account of the current developments in international fisheries issues as well as the government's strategies for fisheries resources (Brian Johnson, 1981).

Concerning the management of marine life and coastal zones, it is believed that the coral reefs on Sudan's Red Sea Coast is highly endangered partly by action of natural enemies and mostly due to man's activities. Some agencies are actively involved in conservation of the Red Sea Coasts including the Institute of Oceanography in Port Sudan and Sudanese Marine Conservation Committee (S.M.C.C.). Also worth of mention is the research programme conducted by the Students of the Institute of Environmental Studies (I.E.S.) on the environmental pollution on the Red Sea Coast.

The above reviews of the major legal aspects governing the environmental and natural resources in the Sudan indicate that:
1) At the present there is no comprehensive and unified environment and natural resources legislations. Existing laws were fragmented and diffused between the different departments concerned.

2) Most of these legislations are out of date giving little attention to the developments and also there are many sectors where legislations have been lacking for years.

3) Most of these laws are not drawn up in the context of environmental management but were statutory instrument to support individual units (e.g., Forest Acts, Wildlife Acts ... etc). Secondly they are derived from the British law and the general context of audience, there is no single corpus of legislation which deals with actions which may degrade the environment.

4) The majority of legislations date back to the colonial period, any amendment made had been superficial i.e., no change in the context. Lastly, what is really absent is not the laws
but the legal (policy) framework, which provides philosophy for environmental management in the Sudan, and the disintegration of the environmental issues between the different agencies which explain why there is no unified policy for the administration and protection of the environment.
4.1 Introduction:

The Gedaref region is the first cultivated area in the Sudan in which the mechanized rainfed farming was introduced. Mechanization first started in the Chademialiya area north of the Gedaref district then extended south and south west of the district.

The region was selected for this study because it reflects closely the impact of mechanized rainfed farming on natural and human environment with time i.e. to see its impact on the old cultivated areas e.g. Chademialiya area and the relatively newly cultivated area e.g. Senna and Ham Seint to be compared with areas not yet put under mechanized farming. This chapter aims to high light on the physical, natural and human environment of the district which will be an important background to trace the changes that occurred in the environment of the district.
4.2. **Location:**

The region lies southeast of Khartoum. It occupies the Southern part of Kassala province in eastern Sudan. It lies between latitudes 12° 49' N and 14° 15' N and longitudes 34° E and 37° E (approximately). It has an area of 76,228 sq. km. (Fig. 6).

It is bounded by Atbara River on the east and the Rocked River on the west and southwest. The region is about 600 meters above sea level.

The nearest town is about 245 miles from Khartoum and 480 miles from Port Sudan, the only sea port. Thus the region is reasonably situated to internal and external trade.

4.3 **Climate:**

The climatic zones of the district were described by Vander Veen (1976) "Travelling from the north to the south through Kassala province one passes through six climatic zones from the desert in the far north to the wet season climate in the southern tip of the district" (Fig. 7).
FIG. 7 CLIMATIC ZONES IN KASSALA PROVINCE

SOURCE: Kassala Province Profile 1980
The northern part of the Gedaref district is semi-arid zone. In this zone, the short dry spell may cause considerable reduction in yield while in the dry monsoon zone it is flooding rather than drought that cause crop failure.

Rainfall is considered an important factor in determining the type and variety of crops to be grown and the cultural techniques which should be used for optimum production.

Rainfall varies from north to south. The average annual rainfall varies from 175 mm at Gao Ragi in the north to 570 mm at Gedaref in the centre to 650 mm at Doku in the south. Rainfall in Gedaref area is markedly seasonal in character, the length of the rainy season fluctuates around four months fall in the period between early June and late September. It reaches its peak in August.

4.1.1 Rainfall Distribution

It is rather the distribution of the individual rain showers within the rainy season which is important for production than the amount. This is
because it is related to the time of sowing, the feasibility of post-sowing operations, the regular supply of water and time of harvest. A recent study in the area by Elroy's et al. (1983) showed that the annual distribution of rains remained fairly constant during the past thirty years. July, August and September are the three months of the rainy season. During these three months 75% of the year's rain falls (table 4).

4.2.6 Water Balance:

The rainfall in the study area is characterized by relatively low intensity. Thus, a considerable proportion of the rain will be distributed in a comparatively larger number of moderate rainfall days. This means that much of the rain will be effective in agricultural sense, since it is available to plants, and therefore contributing in building up moisture.

H. Held (1983), studied the effectiveness of rainfall in the area and found that, there is a short-term fluctuation between surplus and deficiency (Appendix 3). He added that April and
Table 4) **Average Rainfall During the Months of July, August and September.**

<table>
<thead>
<tr>
<th>Year</th>
<th>July (mm)</th>
<th>August (mm)</th>
<th>September (mm)</th>
<th>Total (mm)</th>
<th>Annual %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950-59</td>
<td>155.6</td>
<td>188.4</td>
<td>107.4</td>
<td>553.4</td>
<td>77%</td>
</tr>
<tr>
<td>1960-69</td>
<td>177.9</td>
<td>179.7</td>
<td>65.4</td>
<td>522.4</td>
<td>73%</td>
</tr>
<tr>
<td>1970-79</td>
<td>167.4</td>
<td>167.0</td>
<td>110.6</td>
<td>6.5.5</td>
<td>75%</td>
</tr>
</tbody>
</table>

Source: Galal El Din El Tayeb (1983), EMNA Programme - Geziraf (District).
May have the highest value of water deficiency (which sometimes exceed 200 mm), while the time of surplus include June and July and in some years August.

4.3.3 Environment and Climatic Variation:

ElTayeb and Lewandowski (1983), studied and analysed climatic data (temperature and rainfall) in the area over the past forty years to see if any significant change occurred in either. They concluded that "The temperature did not vary as expected. Rainfall (annual totals and rainfall distribution in the critical months) did not vary significantly over the past forty years. We therefore ruled out climatic change as a possible cause of environmental degradation in the Gedaref district" p. 53. A similar study carried by Andreola (1984) found that, the agricultural climate in the area is characterized by its less variability when it is compared with similar areas in the Sudan or elsewhere in the tropics. He added that the climate in the area has fluctuated from one year to another but not varied for better or worse as thought. This can be seen clearly in
Fig. 6 which shows the annual coefficient of variation of rainfall for the period 1951 - 1981.

4.4. Geology

The Gedaref area is usually assumed to be a flat plain. It is part of the central clay plain which lies between latitudes 10° - 15°N. The Gedaref and its surrounding is located on a high plateau forming a water divide between Atbara to the east and River Rashad to the west. (Salimah, Y. 1968).

4.4.1 Stratigraphy

According to Salimah, Y. (1968), Whitesen (1971) and Buroumeh (1976) the Gedaref district consists of the following geological formations:

1) Basement Complex
2) Rubian Series
3) Volcanic Rocks
4) Superficial Deposits

1) Basement Complex

The pre cambrian basement complex is the most extensive geological formation in Kassala province
(Whitman, 1971). It consists mainly of igneous and metamorphic rocks. Outcrops of the rock formation are found in Gede Insil Nobol series, Jebel Jubel and Gedeb-abeliya.

ii)

The formation:

It covers an appreciable area in Gedeab district. Geologically termed as "Gedeab formation" which includes all those sandstones, sandymudstones and mudstones that crop out in the area around Gedeab and along Ethiopian frontiers and pass laterally into sandstones of Setite valley and Adjigir sandstones. Jebel Samsan and Umbelil are outcrops of the Gedeab formation.

iii) Volcanic Rocks:

This is dominated by tertiary basalt which is surrounded by massive sandstone and mudstone of Gedeab formation. Decomposed basalt acquired different colours ranging from light grey to dark grey and from brown to red. Outcrops of the formation are found on the Gedeab - Sellecto Ridge.

iv) The Superficial Deposits:

The rock of all formations are mostly covered
by thick layer of Quaternary elastic materials. According to Salvini, Y. (1969). These are the result of the decomposition and disintegration of the volcanic rocks. They are mostly heavy clays in the centre and southern parts of the district where the mechanized rainfed farming is practiced. Also, medium coarse textured materials are found in north and east, while river sediments are found along Athara and Bahebd Rivers.

4.32. Hydrology:

The area is traversed by many seasonal water courses. In addition to Athara and Bahebd River, there are two major Khors namely, Khor Abu Faraga and Khor Magana which traverses Gebreif town. Khor Abu Faraga passes immediately north of the town and flows westwards. High floods cause a menace to population, especially in the parts of the town which are situated on the banks of the Khor.

According to the Geological Survey Department and Rural Water Corporation the Gebreif basin is formed mainly of Rubian sandstone and basalt. The Rubian series includes consolidated sediments underlying the basalt. Hard mudstone is interbedded with fairly consolidated...
sandstones of fine to coarse texture. They form isolated basins beneath the basalt. Drilling attained thickness of 600 feet without reaching the base. However, sandstones are non-water yielding, but, the sandstones form the major aquifers in the area (Table 5 shows the ground water potentialities of the Gedaref basin).

4.5. SOILS:

The Gedaref region is the vast plain of clay soils. The average ground slope is approximately 2.5 meters per km. The soils in this region are described as deep, dark coloured, heavy clay soils. The clay fraction varies from 61% to 73% (Laisi, 1953) and it tends to increase south-eastward, coinciding with the increase in rainfall.

The origin of soil materials is believed to be Ethiopian highlands (Jewit 1954). Yet, extensive areas of cracking clay were derived from the decomposition of rocks in situ. Totill (1940) identified areas of chocolate-coloured cracking clay, apparently formed in situ, from basalt, giving character to several areas e.g. around Gedaref and north of Soba. Also, restricted islands of red soils occur in some
Table 5) **Groundwater Potentialities of the Gedaref Basin**

<table>
<thead>
<tr>
<th>Basin of Gedaref</th>
<th>Underflow Recharge Mil. m$^3$/Y</th>
<th>Baseline Abstraction Mil. m$^3$/Y</th>
<th>% of recharge</th>
<th>Gel. M/Y storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>41.7</td>
<td>700</td>
<td>4.2</td>
</tr>
</tbody>
</table>

**Source:** Rural Water Corporation, Khartoum 1976.

**General remarks on groundwater resource of the basin**

- **Present state:** developed
- **Management:** required
- **Future potential:** poor
- **Area for future development and study:** None

**Source:** Gelal El Din El Tayeb (1983), EMA Programme - Gedaref (District).
cross, such as seen at Asase north of Gedero and elsewhere. Wide areas of clay are often found remote from hills, known as "bashadiu".

Suruynah (1976) described the Gadambaliya soil (the north part of the district) as typical vertisol with deep cracking, self mulching, moderately well-drained profiles and high clay content. They are of high cation exchange capacity (C.E.C) and high base saturation, mild reaction and non to slight calcareous matrices, non saline, non-sodic and salt free.

In 1966, a reconnaissance soil survey was carried out in the southern Gedero district (Sunseem and Umuseim) by N.D.D.CO and ILACO. They described the soils of the survey area as having a low inherent fertility status and the availability of nutrients in the surface soils classified as low to very low.

4.6 Vegetation

Generally, the vegetation of the area is largely dependent on rainfall and soil types. According to Harrison and Jackson (1955) the Gedero area lies in

* The Netherlands Engineering Consultants and the International Developments Consultants of Netherlands.
the low Rainfall Woodland Savanna belt on clay. This was subdivided into the following:

i) *Acacia mellifera* Woodland:
   
   a) on dark cracking clays alternating with grass areas (400 - 570mm of rainfall).
   
   b) on soils formed in situ associated with *Commiphora africana* and *Acacia senegalensis* (220 - 500mm of rainfall).

ii) *Acacia seyal* - Balanites Savanna:

   Alternating with grass areas (570-900mm of rainfall).

iii) *Anogeissus - Commiphora hirta* Peach savanna:

   Woodland: (above 600mm of rainfall).

To the north of the *Acacia mellifera* belt lies the Butana region which is an open grassland with patches of *Acacia mellifera* mainly confined to typical sites (Khors). Perennial grasses are almost absent in the Butana region.

Transition from one rainfall belt to the other is defined by the changes in the dominant trees, though grasses show no good line of demarcation.

4.7. Socio- Economic Features:

4.7.1 Population:

Since the introduction of mechanized reinfed
forming in the early 1940's, the Gedaref district became an economically important market for both grains and animals. So, more people are being attracted to this area. In early 1960's the Gedaref town was estimated to have a population of less than 20,000 people.

In 1968 the population of the district was estimated to be 403,032 people and the annual rate increase for the whole Eastern region was 3%. Table 6 shows a high rate of population increase (11.3%) in the period 1973 to 1983.

Table 6: Rate of increase in population for the different councils in the district in the period (1973 - 1983).

<table>
<thead>
<tr>
<th>Area</th>
<th>1973 Census</th>
<th>1983 Census</th>
<th>% of Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Gedaref</td>
<td>126,085</td>
<td>223,909</td>
<td>20</td>
</tr>
<tr>
<td>Southern Gedaref</td>
<td>143,268</td>
<td>223,782</td>
<td>53</td>
</tr>
<tr>
<td>Western Gedaref</td>
<td>83,524</td>
<td>88,609</td>
<td>5.3</td>
</tr>
<tr>
<td>Gedaref Town</td>
<td>72,395</td>
<td>16,477</td>
<td>47.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>496,995</strong></td>
<td><strong>552,557</strong></td>
<td><strong>11.3</strong></td>
</tr>
</tbody>
</table>

*Source:* Gedaref Municipal Council, 1983
4.7.2 Landuse:

Traditionally, the people of the Deseret district have been either semi-nomadic pastoralists herding cattle, camels, sheep and goats; or subsistence cultivators growing durra. This mode of subsistence showed a high level of adaptation to the environment by the different users.

Now four major types of landuse are encountered in the district (Fig 9):

1) Traditional cultivation:

Several systems of rainfed agriculture are found, such as shifting cultivation in the savanna woodlands, harrig (fire burning) cultivation in grass savanna and (terraces) cultivation in the arid parts.

Production from the traditional cultivation is very low and many hazards are encountered such as drought and/or water logging, plant diseases, pests... etc.

These, in addition to bad management practices are responsible for the poor yield obtained.

ii) Traditional pastoralism:

This is mainly confined to the northern half of the district, the Almajid. This area was described...
FIG. (1)
GEDAREF DISTRICT LAND USE

LEGEND
- Railway
- Highway
- Seasonal Road
- Irrigated Agriculture
- Mounted Mechanized Farms
- Grazing and traditional farming
- Areas receiving high concentration of nomads and high grazing pressure

SOURCE: Othai El Din El Tyeb (1983),
EIMA Programme, Gedaref (District)
the best rangeland mainly for camels and sheep. This was largely due to the occurrence of good grazing fodders. This area was heavily grazed. Recently, it is reported that *Helminthosporium* sp. is disappearing from vast areas of Butana.

The northern district (Butana) is considered arid rangeland, so reinfed cultivation is sporadically practical through term cultivation or on low-lying water receiving sites.

iii) *Irrigated Agriculture:*

These are situated in the northeast in Kufra and in the southwest of Rehad schemes.

iv) *Mechanised rainfed agriculture:*

Modern rainfed agriculture using tractors and disc harrows and sometimes mechanical harvesters is found in this semi-arid part of the clay plain. It dominates the southern part of the district.

Land is leased by the State for individual investors whereby each individual is allotted "a farm". The size of the farm ranges from 1000 to 1500 feddans. These schemes are managed by both private and government sectors. Sometimes rotations of crops, sesame...
and follow with or without cotton are applied, but often a piece of land is cropped with durra until the land loses its fertility and then abandoned.

4.8 Development in Gedaref district:

Development in the district started in early 1940's with the introduction of mechanization (Agbawi, 1963). At that time the decision to introduce mechanization was political rather than economic (Suliman, 1977). Later in the following years, the economic importance of mechanized rainfed farming became recognized in all development plans. Despite the economic recognition, the mechanized rainfed farming is criticized as being a major cause of environmental deterioration in the district. To understand the role it played and to assess its impact a brief background is necessary.

The Mechanized Farming Corporation (M.F.C.) was established in 1968 (Act No.14) to act as a main agency for the promotion of large scale rainfed agriculture. In 1975, the M.F.C. has a new Act which defined the responsibilities of the corporation in the following:

i) Survey, allocate, demarcate and distribute schemes to farmers.

ii) Assist the private investors and direct their
attention to the best agricultural techniques.

iii) Promote agricultural research.

iv) Provide credit to farmers on reasonable terms

v) Operate state farms

vi) Provide social services.

It has been noted that emphasis during the past years concentrated primarily on survey, demarcation and distribution of schemes and operate of state farms. There had been very little activity in other aspects of responsibilities.

Since the introduction of mechanisation in the district more emphasis was given to horizontal expansion rather than to vertical expansion. In the year from 1950 to 1952 the total area under mechanized rainfed farming in the district was 36,124 feddans. At present the area exceeding 3 million feddans, half of this area is undemarcated or unauthorised by the I.F.O. So, there is a spread without any control by concerned technical agencies e.g. I.F.O. or Landuse department.

A general evaluation of these schemes indicates that there are many shortcomings in the planning of these schemes with site selection, nomadic rights, stock routes and wildlife sanctuaries.
The development of mechanized farming in the district and its spread without any control or appropriate environmental measures resulted in serious deterioration in the grazing resources, forest resources and loss of soil fertility. The following section and the coming chapter will evaluate the impact of mechanized rainfed farming on these natural resources.

4.6.1 Impact of mechanized rainfed farming on the grazing resources:

The development of mechanized farming in the district did not take into consideration the animal resources which gradually pushed out the traditional grazing lands. This, together with the ever-increasing livestock numbers resulted in high pressure on the grazing lands, leading to overstocking and consequently overgrazing. Recently, the overstocking rate in the district was estimated to be 8.36% (El Zeyad and Lewandowski, 1983). This had more bearing on the environmental degradation in the district. A.M. El Hassan (1981) found that large areas of the district had been overgrazed to a point that now looked bare ground. He also found that there was decrease in silt and clay content of the overgrazed areas which indicates
the occurrence of erosion.

Generally, the expansion of mechanized schemes into former grazing lands blocked traditional human routes and contributed to desertification (El Tayeb and Lewandowski, 1983).

4.6.2 Impact of mechanized rainfed farming on forest resources:

The development of mechanization had also been at the expense of tree cover in the district since the whole area was devoted for crop production. Large scale clearance of tree cover is expected to induce many changes. This was clearly seen in the decrease of species diversity as annuals, biennials and perennials has been replaced by crops (Bubawi, 1982).

The importance of tree cover can not be overemphasized especially in areas prone to flooding and erosion. According to Bubawi and El Rikhali (1978), negligence of conservation measures such as leaving tree cover between furrows (shelter belts) and around natural drains in the newly deforested areas for mechanized crop production resulted in gully erosion. El Tayeb and Lewandowski, (1983), found that the width of Khur Abu Farga increased from about 21 meters in 1961 to about 52 meters.
in 1962 as a result of deforestation of its catchment area for mechanized rainfed farming. They attributed the catastrophic floods, which the district witnessed, to this magnitude of deforestation.

Studies carried out in China and elsewhere found that shelter belts played an important role in increasing soil moisture and consequently increasing yields and production (Advisory Committee on the Sahel, 1983).

4.3.3 Impact of mechanised rainfed farming on the soil.

The rapidly expanding mechanization caused degradation in the soils of the district. This was clearly felt in the reduction of yields during the last years. According to El Tayeb and Losiewski (1983) poor management, bare monocropping and soil impoverishment contributed to low yields. This degradation in soils manifested itself in the degradation of the soil structure, soil texture and soil fertility.

Since the introduction of mechanisation in the area different types of machines were imported without testing their suitability to the soils. Some of these proved to be harmful to the soil. In a study carried out by the National Council for Research...
(1973), it was found that the disc level disc was not doing a satisfactory job as a soil controlling implement and did not allow deep penetration. The continuous use of these machines was expected to cause drastic changes in physical conditions of the soils. The loosening, pulverization and pressure applied to the soil by various machines are found to cause change in size and amount of air voids (Al-Khayat and S.S. Green, 1973). The continuous discing and to the same depth with time may lead to formation of hardpan in the sub soil. Al-Khidhir (1991), found that there was a direct positive correlation between discing frequency and development of compaction layer. He also added that "the compaction layer is expected to become a hardpan, if the discing is allowed to continue to the end of the twenty five years of the contract between the farmer and the corporation. According to Haynes (1977), this crust formation was responsible for the run-off and clay failure in the district. The rapid expansion of mechanization was also blamed for degradation of soil fertility and hence decrease in yields. Usually farmers cultivate the same scheme for long periods until fertility decline and the yield drops. Then the field is abandoned and farmers search
For another location, in this way vast eroded and exhausted lands are left, which are useless even to more sustainable forms of agriculture (Bron, 1963). Deterioration of soil fertility can also be due to complete negligence of soil conservation measures such as shelter belts, crop rotation and fertilizer application.

4.7 Impact of mechanized ranching on social environment

The effect of mechanized ranching in the district must also be seen in relation to socio-economic factors. The expansion of mechanized ranching squeezed the nomads and traditional farmers out of some of their traditional lands.

The extent of mechanized ranching on the land which did represent a major grazing resource forced the nomads to be confined only into small shrinking areas. As mentioned, this, together with increase number of cattle led to overstocking and overgrazing. The effect of this resultant poor grazing conditions in that, nomads are forced to supplement their herd's food by buying fodder, especially in the critical months of summer. This required nomads to supplement their
income since they are not willingly selling their animals. In this way social and economic structure had been disturbed since part of the family settled with few animals while others move with the rest of animals to work for wages in these schemes.

Also, the expansion of mechanized farming had been at the expense of traditional cultivation in the district. Now, this mode of cultivation is in state of break down. It is confined to small scattered places in the southern and northern parts of the district.

The advent of mechanization changes the mode of acquiring the land. The land had been either privately or tribal owned. Now, the land changed to be state owned. So, traditional farmers change from landlords to landless. Traditional farmers after losing their land "productive asset" they are forced to change their mode of life and work in the schemes for wages.

Also, clearance of trees by mechanization specially those used to produce Gum Arabic had affected the traditional farmers negatively. By losing this type of production they lost a substantial part of income and hence increase poverty. However, some traditional
farmers get an advantage from the introduction of mechanization in the area by 'owning' schemes. But these usually constitute only a small portion of the population.

From the above discussion, it is clear that neither noose of the district nor traditional farmers had derived much benefit from introduction of mechanization other than being seasonal labourers. On the other hand, benefits are concentrated in the hands of few leaseholders. Most of them are merchants having little or no agricultural knowledge (Igebawi, 1969). In this sense, mechanized farming is an option only for small number of the population, due to high cost of production and hence the local peasants are not the target group of the planners.

This brief outline of the different impacts will be substantial in the following chapter. The field work carried out during November 1963 to March 1964 provides informations and have data to assess the negative impacts of the uncontrolled expansion of mechanized rainfed farming in the district.
CHAPTER V

Resource Management in the Gedaref District

5.1 Institutional Arrangement:

In chapter II the institutions involved in environmental management at the national level were discussed. The analysis showed some defects that manifested themselves in the lack of clear environmental policy, lack of land use plans, lack of coordination and fragmented projects with little concern for environmental protection. All these shortcomings at the national level had their impacts at regional and local level.

The Gedaref district gives the best example of the conflicts between regional interests and national interests and ecologists interests for environmental protection.

Development that took place in this district is mainly related to the spread of mechanized agriculture and as noted earlier in the absence of prudent policy, this development will be exploitive and irrational.

The conflicts between national and regional interests is best seen in the priorities of each party. The N.F.C. with its regional office in Gedaref are interested in promoting the spread of reinfed farming in the district to supply the ‘grain needs of the country. The
local inhabitants traditionally utilized the area for animal rearing with limited cultivation. Now, and as a result of the expansion of the mechanized farming, the local inhabitants are pushed out of their traditional areas and confined only to small, shrunk, fragile areas not capable of adequately supporting their way of life.

Most of the expansion of mechanized rainfed farming in the district was unplanned and unauthorized. This, unplanned expansion provide the best example for the conflicts between national and regional interests on one hand and between government agencies on the other hand responsible for land allotment. The underestimated or unplanned schemes established by individuals who got approval from commission or local authorities to start mechanized farming operations. Hence, it continued without any control by the concerned technical agencies responsible for mechanized agriculture. So, they do not receive adequate (central) government support in provision of technical and advisory services or important facilities. This type of cultivation is responsible for most of the degradation that occurred to the natural resources in the district. The M.P.C.
claimed that they are not to be blamed for this degrada-
tion because the corporation did not authorize or
legalized these schemes. This divided administrative
responsibilities is apt to have adverse influence on
land resources use. On the other hand the allocation of
described schemes is supposed to be done by a team
composed of members from all departments of natural
resources concerned. Also, selection of schemes are
supposed to take into consideration land suitability,
right of nomads to move through stock routes, forest
reserves... etc, but the present situation indicates
that most of these schemes expanded at the expense of
forest and grazing areas in the district. All these
developments create hazards of soil degradation, gully
erosion and natural resources depletion. These problems
were further accentuated by the inefficiency of the
institutional control. The original plan for mechan-
ised farming assumed integration of contour ploughing,
rotation planting and windbreaks, but the institutional
and regulatory infrastructure to back up such conser-
vation measures were lacking.

All these shortcomings resulted in severe degrada-
tion of the environment in the district, shown in
overgrazing of rangeland, deforestation, deterioration of soils, declining productivity and consequently degradation of human environment. This chapter attempts to quantify these variables and assess the degree of degradation that took place in the Gedera district.

5.2. Overgrazing:

The northern part of the district, the Butane, with its limited amount of rainfall (less than 300 mm) is only suitable for grazing. Traditionally, this area is known as one of the best grazing lands because of the occurrence of *Bulphasus* sp. (silk) and other palatable grasses. Recently, it is reported that Bulphasus is disappearing from vast areas of Butane (Harison and Jackson, 1995).

This good grazing land became the first target of the mechanized rainfed agriculture. It started in the Ghasambally area to the north of Gedera and then expanded rapidly to the south and south west. As a result more grazing lands is sacrificed to croplands. This change in landuse subject the environment to great stress. The expansion on traditional grazing lands pushed the pastoralists to more marginal and
Fragile areas. As a result large number of animals were concentrated in the drier part of the district leading to overstocking (table 7), accompanied by overgrazing and removal of vegetative cover. The degree of cover removal is reported by many studies carried in the area (table 8).

The advent of mechanization to the south and south west of the district also had been at the expense of the dry season grazing areas for the nomads. So, all development achieved in the district was planned at the central level without any local involvement. This shows clearly the difference in perception between the two groups. The large animal resources are totally ignored without being integrated in cropping system. Animal producers tried to make use of the crop residues but total forage produced often fell short of the requirements as shown in table (?). It is worth to mention here that not all of the total forage is available for grazing. This is because of the hostile attitudes of the scheme owners towards nomads. They often prevent nomads from using the scheme areas for the fear that animal droppings may carry seeds of harmful weeds which might offset next season's production. So, many
Table 8) Shows the % of berald in the district from north to south.

<table>
<thead>
<tr>
<th>Site</th>
<th>% of area covered with vegetation</th>
<th>% of berald</th>
</tr>
</thead>
<tbody>
<tr>
<td>El-Safic</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Suro</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>El-Subag</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>El-Sudou</td>
<td>16</td>
<td>34</td>
</tr>
<tr>
<td>Sumsem-Gedaref</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>Umn Soimat Schaimes</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>Seraf seid</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Basendu</td>
<td>94</td>
<td>2</td>
</tr>
<tr>
<td>Tyha</td>
<td>98</td>
<td>2</td>
</tr>
</tbody>
</table>

farmers burn the crop remains and sell the cut stalks in the market (Table 9).

Responding to this the nomads always invade these schemes whenever they find a chance. Evidence to this about 56 per cent of the scheme owners mentioned that they suffer invasion by nomadic tribes. As a result conflicts arise between nomads and farmers. This is indicated by the increase number of police cases resulted from this invasion (Table 10).

Table 10: Shows the number cases reported to the police as a result of invasion by nomadic tribes in some of the police stations in the district in 1982.

<table>
<thead>
<tr>
<th>Centre</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gedaref</td>
<td>2</td>
<td>16</td>
<td>0</td>
<td>5</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Ghinda Boliya</td>
<td>25</td>
<td>23</td>
<td>11</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Abwot</td>
<td>22</td>
<td>16</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>55</td>
<td>23</td>
<td>16</td>
<td>17</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 9) Shows disposal of crop residues in mechanised schemes in the district:

<table>
<thead>
<tr>
<th>Method of disposal</th>
<th>% of respondent to each method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- burning</td>
<td>32%</td>
</tr>
<tr>
<td>2- allow animals to graze</td>
<td>32%</td>
</tr>
<tr>
<td>3- cut and pecked</td>
<td>27%</td>
</tr>
<tr>
<td>4- mulching</td>
<td>5%</td>
</tr>
<tr>
<td>5- others</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Source: Field work data, 1984

Table 11) Shows the crop left fallow in the Chaudhary schemes for the season 1982/83:

<table>
<thead>
<tr>
<th>S.no</th>
<th>Area cultivated in hectares</th>
<th>Area left fallow in hectares</th>
<th>Fallow days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-</td>
<td>planned mechanized schemes</td>
<td>348.900</td>
<td>10,000</td>
</tr>
<tr>
<td>2-</td>
<td>Un planned mechanized schemes</td>
<td>68.650</td>
<td>6,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>417.550</strong></td>
<td><strong>16,000</strong></td>
</tr>
</tbody>
</table>

Source: M.E.O, Cereal office, 1983
Another factor contributing to unavailability of forage in the mechanized schemes is that, crop left fallow comprise small proportion of the total cultivated area. For example, in the Shadumbuliyu area, which is almost devoid of tree cover, the crop left fallow amounted to 4,82 per cent of the total cultivated area for the season 192/03 (table 11).

From the above it is clear that, the mechanized rainfed farming has failed to meet the demand for forage and thus, the livestock has remained surplus with respect to pasture carrying capacity. The result has been overexploitation of grazing lands and over-grazing. These facts clearly indicate disregard of conservation measures. The laws and regulations pertaining to mechanized schemes were not implemented at the district level leading to deterioration of grazing resources and appearance of new unpalatable species and disappearance of perennial grasses. Evidence for this is drawn from the interviews made with nomads and studies done in the area by El-Hawza (1901). From those studies it was found, before the expansion of mechanized farming printable plants were close to the nomadic camps. But, recently the conditions had changed to such an extent that herders spending 2 to 4 days
searching for good pastures during the dry season. 
Grazers were found to travel even longer distances 
till they reach the Ethiopian border as a result of 
increase range deterioration.

5.3. Deforestation

Forest resources of the area also become exposed 
to combine influence of large scale destruction for 
mechanized agriculture, wood extraction for fuel, 
timber, fodder and uncontrolled fires, (table 12).

In the last forty years, the mechanized agriculture 
expanded rapidly at an increasing rate. It expanded 
from 12,000 feddans in 1945 to over 3 million feddans 
in 1983. This development led to large scale clearance 
of tree cover. According to the forest regulations, the provincial Forestry Administration retains 
the right over the utilization and removal of trees 
in the schemes on it is government land even outside 
the reserves for certain purpose. But, in reality, 
the Forestry Administration seems to have no control 
over the area allotted for mechanized schemes.

The recommendations of the Mechanized Farming 
and the Forestry Administration requires that about
Table 12) Shows the perceived factors of degradation in the vegetative cover:

<table>
<thead>
<tr>
<th>Causes of vegetative cover degradation</th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- expansion of cultivation</td>
<td>14</td>
</tr>
<tr>
<td>2- commercial production of fuelwood and charcoal</td>
<td>57</td>
</tr>
<tr>
<td>3- increased number of human and livestock population</td>
<td>50</td>
</tr>
<tr>
<td>4- impact of nomads</td>
<td>39</td>
</tr>
<tr>
<td>5- others</td>
<td>29</td>
</tr>
</tbody>
</table>

Note: The respondents mentioned more than one reason.

Source: Field work data, 1984
5 per cent. of land of each scheme should be left under forest as a shelterbelt. In fact, these recommendations were ignored almost by every scheme owner. So, it is normal to see the schemes devoid of any tree cover. Schemes were cleared for variety of reasons; the perceived need to reduce competition for moisture between grown crops and trees, to eliminate roosts for granivorous birds such as Quela quela (black faced dicae), to eliminate patches that inhibit crop growth and to facilitate the use of mechanization especially tractors (table 13).

Another contributing factor to deforestation was the increase of population as a result of immigration. During the last few decades there had been steady movement of population from other regions of the Sudan and from outside to the district to work as labourers in the mechanized schemes. In the district there is now over 50 thousands Brittan and Ethiopian refugees. The increase in population has inflated the wood demand and thus firewood had been drastically over exploited around the settlement centers. It was estimated that on area more than 10 km sq. around Gedaref had been totally deforested.
Table 13: Reasons behind not following recommended shelterbelts in the mechanized scheme in the district.

<table>
<thead>
<tr>
<th>Reasons</th>
<th>% of Respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- trees will compete crops for water</td>
<td>40</td>
</tr>
<tr>
<td>2- trees attract birds</td>
<td>32</td>
</tr>
<tr>
<td>3- trees hinder mechanized operations</td>
<td>46</td>
</tr>
<tr>
<td>4- trees will reduce crops that can be used for crops</td>
<td>30</td>
</tr>
<tr>
<td>5- others</td>
<td>13</td>
</tr>
</tbody>
</table>

Note: The respondents mentioned more than one answer.

Source: Field work data.
Table 12 indicates that wood and charcoal are the most important types of biomass used in the district. The average per head consumption was estimated to be 1.5 cubic meters of wood annually (U.B.E., 1982). Adding to that, much of the wood is not converted efficiently into charcoal increasing the pressure on forest resources.

Also, in the last few decades, the district has witnessed an intensive commercial charcoal production activity. Large quantities of charcoal produced in the district were transported to the large consuming centres outside the region. The result has been more and more areas cleared to meet these demands (Fig 10). The figure shows the steady increase of area cleared for charcoal production. Table 15 reveals that charcoal production increased drastically during the last nine years to over 112%, while the forest land cleared between 1972/73 and 1982/83 increased by 301.57% at an average annual rate of increase of 25.45%. It was estimated that the area cleared for charcoal production had shifted to the south by an average of 15 - 20 km per annum.

The situation is further exacerbated when we consider that large quantities of charcoal is not accounted for here because of smuggling. Foresters in the
<table>
<thead>
<tr>
<th>Type</th>
<th>Amount</th>
<th>Cons</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sour: * 10
FIG (10)

AREA CLEARED FOR CHARCOAL PRODUCTION IN THE GEDAREF IN THE PERIOD (1977/78 - 1980/81)

AREA IN 1000 FEDDANS


SEASON

SOURCE: Data compiled from Forest Department Gedaref (District) 1981
Table 15: Shows the increase in charcoal production in the district during the period 1972-1981

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (in sacks)</th>
<th>Forestland cleared (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972/73</td>
<td>470,307</td>
<td>94,661.4</td>
</tr>
<tr>
<td>73/74</td>
<td>356,311</td>
<td>73,262.2</td>
</tr>
<tr>
<td>74/75</td>
<td>325,352</td>
<td>79,870.4</td>
</tr>
<tr>
<td>75/76</td>
<td>534,190</td>
<td>116,833.0</td>
</tr>
<tr>
<td>76/77</td>
<td>612,821</td>
<td>123,564.2</td>
</tr>
<tr>
<td>77/78</td>
<td>500,100</td>
<td>160,020.0</td>
</tr>
<tr>
<td>78/79</td>
<td>967,200</td>
<td>197,440.0</td>
</tr>
<tr>
<td>79/80</td>
<td>1,201,000</td>
<td>240,200.0</td>
</tr>
<tr>
<td>80/81</td>
<td>1,527,716</td>
<td>285,543.2</td>
</tr>
</tbody>
</table>

District estimated that the illegal charcoal production is at least twice as high as legal production.

The reserve forests, provincial or central are now experiencing intensive wood cutting to meet the increasing demand for charcoal. This is due to high prices of wood and charcoal. Ten years ago the price of a bundle of wood ranged from 2 to 5 (piasters). Now, the same bundle is sold for over 150 (piasters). The same thing applies for charcoal prices which experienced dramatic increase (table 16).

Even though the forestry authorities are not capable of meeting the demand for charcoal, nothing is done for the afforestation programme and the reserve forests have been neglected because of lack of funds. Table 17 indicates that the forestry administration budgets are inadequate to meet even a minimum of the efforts required for extension and enforcement of laws and regulations. So, foresters become unable to carry out even a "defensive policy" of protecting forestry reserves and the demand of improved resources management, monitoring and policy enforcement.

* not licensed
### Table 16)

**Charcoal prices in Godeof town during the period 1979-1982.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Minimum price L.S</th>
<th>Maximum price L.S</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979/80</td>
<td>1,750</td>
<td>3,000</td>
</tr>
<tr>
<td>80/81</td>
<td>2,250</td>
<td>3,750</td>
</tr>
<tr>
<td>81/82</td>
<td>2,750</td>
<td>3,900</td>
</tr>
<tr>
<td>82/83</td>
<td>3,250</td>
<td>5,600</td>
</tr>
</tbody>
</table>

**Source:** Forestry Administration, Godeof office, 1983.

### Table 17)

**Money inputs and credits for Forestry Administration, Godeof office during the period 1979-1982.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Money Inputs (L.S)</th>
<th>Credits (L.S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979/80</td>
<td>196,236,180</td>
<td>5,100</td>
</tr>
<tr>
<td>1980/81</td>
<td>304,366,110</td>
<td>7,250</td>
</tr>
<tr>
<td>1981/82</td>
<td>322,016,310</td>
<td>13,051</td>
</tr>
</tbody>
</table>

**Source:** Forestry Administration, Godeof office, 1983.
5.4 Declining Gum Arabic Production:

The increased wood clearance for mechanized rainfed farming has also been reflected in the declining Gum Arabic production, which is considered an important source of hard currency to the country and source of supplementary income to traditional farmers in the area. Although the available data represents production up to 1962, but it shows a clear decline from a peak at 1965 to a minimum in 1980. From 1980, there is a slow rise but still shows very low production. It seems that the factors behind this decline are complex including tree falling, drought and may be lack of interest in the industry itself because of the low price incentives and land tenure arrangements which is based on crop sharing. (Fig. 11).

5.5 Soil Degradation:

The term soil degradation is used to indicate the reduction of both the quantitative and qualitative productive capacity of the soil.

The Gadoof soils are known of their moderate fertility. Experience showed that they can be exploited for four years of continuous cropping, but
Figure 11: Production of Gum Arabic in the Gedaref in the Period (1970/71-1982/83)

Source: Data compiled from Forest Div. Department Gedaref (Dir. Forest) 1983
after these years yields usually fell off and soils become infertile as indicated by the appearance of certain types of harmful weeds.

In this study the signs of soil degradation are grouped into:

1) Change in soil texture
2) Change in soil structure
3) Change in soil fertility
4) Drop in yields per sadan.

5.5.1. Change in soil texture:

The texture of the soil is usually determined by the size and distribution of soil particles. The results of mechanical analysis carried on samples collected during the field work were tested statistically. The results of the analysis of variance (ANOVA) and the least significant difference between treatments are presented in Table 18.

From Table 18 it is clear that there is a reduction in clay content or increase in sand particles with the increased time of cropping. This change is found to be statistically highly significant and more prominent in old cultivated areas of Chadambeliya.
Table 10: Statistical analysis for the clay content of soils in the selected areas

a- Analysis of Variance (ANOVA Table)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>obs. F</th>
<th>Tabul. F</th>
<th>as 5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>909.65</td>
<td>2</td>
<td>444.8</td>
<td>7.3750</td>
<td>3.35</td>
<td>251</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>1632.83</td>
<td>27</td>
<td>60.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2522.48</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b- LSD Test for Significance

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean</th>
<th>ST. error</th>
<th>1 - 2</th>
<th>Difference</th>
<th>LSD</th>
<th>as 5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83.36</td>
<td>2.46</td>
<td>9.76**</td>
<td>5.0430</td>
<td>5.8785</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>73.62</td>
<td>2.46</td>
<td>22.76**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>70.64</td>
<td>2.46</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean = 75.25

* = significant at (P<0.05)
** = significant at (P<0.1)

LSD = Least significant difference.
It is believed that soils usually become degraded when sand particles increase in the top layer either because of removal of fine particles by wind or water or addition of sand particles from adjacent areas. Thus continuous cropping for longer periods leads to reduction of clay content and thus soil degradation. This process is further accentuated by the removal of vegetative cover which prevents transportation of finer particles by wind or water. This is because vegetative cover hold the fine soil particles in an aggregate form and so hinder its removal.

The clay content of the soil is an important factor in moisture availability especially in areas of limited rainfall like northern Saskatchewan. According to Brady (1974), the soil capacity to hold moisture increases with the increasing silt and clay content. From Table 15, it is clear that lower moisture content was found in the analysis of soil samples representing the old cultivated areas. So, there is decrease in saturation percentage (SP) with longer periods of cropping. This decrease in SP coincides with the decrease of clay content of the soil. It is believed that both the clay content and the saturation percentage (SP) of
Table: 19) Statistical analysis for the xy of the soils in the selected areas

da) Analysis of variance (ANOVA Table)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>obs.</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>1615.88</td>
<td>2</td>
<td>807.94</td>
<td>7.3627</td>
<td>3.35</td>
<td>2.31</td>
</tr>
<tr>
<td>Residual</td>
<td>2997.38</td>
<td>27</td>
<td>109.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4673.26</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) LSD Test for significance:

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Means</th>
<th>St. error</th>
<th>Difference between treatments</th>
<th>LSD (meas)</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>94.32</td>
<td>3.31</td>
<td>$T_1 - T_2 = 13.72^*$</td>
<td>6.792</td>
<td>9.172</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>80.2</td>
<td>3.31</td>
<td>$T_1 - T_2 = 16.92^{**}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>3.31</td>
<td>$T_2 - T_3 = 3.2$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean = 83.71
a soil are important measures of soil degradation. Generally, reduction in clay content or increase of sand particles together with reduction in SP in the old cultivated areas indicate the occurrence of degradation. Therefore the hypothesis that states bad management practices of farmers in the mechanized rainfed schemes resulted in soil degradation is upheld since continuous cropping of the same schemes resulted in degradation of soil texture.

5.5.2 Change in Soil Structure:

For evaluating the change in soil structure, a soil resistance to penetration was done. Measurements were made after the harvesting season and under dry conditions. Some of the results are presented in table 20 and plotted in Fig. 10.

From table 20 it is clear that undisturbed (unploughed) soils gave higher soil resistance than other samples. Soil resistance to penetration in undisturbed soil is found to range from 5.35 kN/m² at the cone depth to 11.2 kN/m² at the depth of 2.54 m/m².

Also, higher resistance to penetration observed in shallow ploughed areas compared with deep ploughed
Table 20: Soil resistance to penetration (kg/cm²)

a) undisturbed soils (forests)

<table>
<thead>
<tr>
<th>Cone</th>
<th>2.54</th>
<th>5.08</th>
<th>7.62</th>
<th>10.12</th>
<th>12.7</th>
<th>15.24</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.95</td>
<td>11.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.7</td>
<td>11.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.76</td>
<td>10.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.79</td>
<td>10.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.96</td>
<td>11.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.96</td>
<td>11.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.90</td>
<td>11.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Shallow ploughed soils

<table>
<thead>
<tr>
<th>Cone</th>
<th>2.54</th>
<th>5.11</th>
<th>8.39</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.32</td>
<td>3.64</td>
<td>5.11</td>
<td></td>
</tr>
<tr>
<td>0.175</td>
<td>2.34</td>
<td>4.55</td>
<td>8.89</td>
</tr>
<tr>
<td>0.21</td>
<td>2.8</td>
<td>4.62</td>
<td>8.38</td>
</tr>
<tr>
<td>0.21</td>
<td>2.7</td>
<td>4.76</td>
<td>8.68</td>
</tr>
<tr>
<td>0.14</td>
<td>2.6</td>
<td>4.60</td>
<td>10.01</td>
</tr>
<tr>
<td>0.21</td>
<td>2.4</td>
<td>4.12</td>
<td>7.84</td>
</tr>
<tr>
<td>0.35</td>
<td>2.36</td>
<td>4.55</td>
<td>9.59</td>
</tr>
</tbody>
</table>

2/
Cont. Table: 20)
c) deep ploughed soils

<table>
<thead>
<tr>
<th>Conc</th>
<th>2.54</th>
<th>5.09</th>
<th>7.68</th>
<th>10.12</th>
<th>12.7</th>
<th>15.24</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.175</td>
<td>0.182</td>
<td>2.24</td>
<td>5.25</td>
<td>7.14</td>
<td>8.96</td>
<td>10.78</td>
</tr>
<tr>
<td>0.175</td>
<td>0.245</td>
<td>2.31</td>
<td>6.325</td>
<td>8.4</td>
<td>10.01</td>
<td>10.78</td>
</tr>
<tr>
<td>0.154</td>
<td>0.21</td>
<td>2.27</td>
<td>4.76</td>
<td>7.21</td>
<td>9.59</td>
<td>10.01</td>
</tr>
<tr>
<td>0.175</td>
<td>0.245</td>
<td>2.45</td>
<td>6.65</td>
<td>7.75</td>
<td>8.96</td>
<td>11.2</td>
</tr>
<tr>
<td>0.134</td>
<td>0.253</td>
<td>2.03</td>
<td>5.65</td>
<td>8.60</td>
<td>9.03</td>
<td>11.2</td>
</tr>
<tr>
<td>0.114</td>
<td>0.102</td>
<td>2.03</td>
<td>6.66</td>
<td>6.72</td>
<td>8.02</td>
<td>10.01</td>
</tr>
<tr>
<td>0.21</td>
<td>0.196</td>
<td>2.24</td>
<td>6.025</td>
<td>8.05</td>
<td>9.1</td>
<td>11.06</td>
</tr>
<tr>
<td>0.337</td>
<td>0.42</td>
<td>2.55</td>
<td>7.21</td>
<td>8.89</td>
<td>9.8</td>
<td>12.04</td>
</tr>
</tbody>
</table>

- 150 -
FIG (12) SHOW SOILS RESISTANCE TO PENETRATION

TREATMENTS
- Undisturbed
- Conventional ploughed
- Deep ploughed

RESISTANCE (N/CM²)

Depth (cm)

 PENETRATION DEPTH (CM.)
allow better penetration. In the area under study usually the farmers plough the soil to a constant shallow depth not exceeding 5 cm. So, the result had been very resistance to penetration. The soil resistance to penetration could affect the growth of crops either through its effect on root penetration, or through its effect on soil water penetration. Tyler et al. (1966) found that root penetration was drastically reduced when soil strength increased to 25 PSI. A recent study in the area by El-Khilil (1961) suggested that mechanized farming may be disturbing the soil water balance in the ploughed layer by increasing soil water surplus and creating run-off and floods. Also, Beggiah (1979) found that poor infiltration rate (1.5 to 2.6 m/h) was observed in Chadenkaliya area which is the oldest cultivated area.

So far it is clear that continuous shallow ploughing and to the same depth, which is the common practice in the area, increase resistance to penetration.
and hence degrades the soil structure.

5.3. Change in soil fertility:

It is a common practice in the area to find that farmers continuously cultivate the same scheme (plot) for a number of years without proper management practices, until the soil is exhausted and productivity drops. In this study it is shown that about 75% of the farmers cultivate the same scheme (plot) for more than 5 years. The effect of this practice is clearly seen in the change of soil fertility. According to Brady (1974) the cumulative effect of crop production over a period of years may rapidly decrease the limited quantities of these elements originally present in the soils. Tests were carried out to determine the level of some chemical properties of the soils. Table 21 indicates that a significant variation was observed for the nitrogen content of the soils ($)$. It tends to decrease in all cultivated areas especially in areas cultivated continuously for longer periods. Similar results were also obtained for organic matter of the soils. The organic content tends to decrease with the increased years of cropping (table 22). The organic matter is found to be higher in controlled areas.
Table: 21) **Statistical analysis for the Nitrogen content (N%) of soils in the reclaimed area:**

a) **Analysis of variance (ANOVA Table):**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>Tabular F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>3.84E5</td>
<td>2</td>
<td>1.92E4</td>
<td>5.36</td>
<td>3.35</td>
<td>2.51</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>3.97E3</td>
<td>27</td>
<td>0.36E1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13.91E1</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) **LSD Test for significance:**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean</th>
<th>Standard Error</th>
<th>Difference between Treatments</th>
<th>LSD 5%</th>
<th>LSD 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.4X10^-4</td>
<td>1.5X10^-4</td>
<td>0.61X10^-4</td>
<td>0.52X10^-4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.3X10^-2</td>
<td>0.5X10^-2</td>
<td>0.85X10^-2</td>
<td>0.52X10^-2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.96X10^-2</td>
<td>0.15X10^-2</td>
<td>0.34X10^-2</td>
<td>0.52X10^-2</td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean = 1.92 X 10^-2
Table: 22) **Statistical analysis for the organic carbon content of soils in the selected zones**

a) **Analysis of variance (ANOVA Table)**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>obs. F</th>
<th>Tabular F</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>0.41</td>
<td>2</td>
<td>0.2</td>
<td>15.6013</td>
<td>3.35</td>
<td>2.51</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>0.28</td>
<td>27</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.68</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) **LSD Test of significance**

<table>
<thead>
<tr>
<th>Treatments Means ST. difference</th>
<th>Between error treatments means</th>
<th>LSD</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0.77 0.03  \text{T}_1-\text{T}_2 = 0.13</td>
<td>\text{T}_1-\text{T}_3 = 0.20</td>
<td>**</td>
<td>0.06156</td>
<td>0.08333</td>
</tr>
<tr>
<td>2 0.64 0.03  \text{T}_1-\text{T}_3 = 0.28</td>
<td>\text{T}_2-\text{T}_3 = 0.15</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 0.49 0.03  \text{T}_1-\text{T}_3 = 0.15</td>
<td>\text{T}_2-\text{T}_3 = 0.15</td>
<td>**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean = 0.63
(area being under long periods of fallow) due to
decomposition of fallen leaves and litter. On the
other hand, farmers in the area rarely mulch crop residues.
This is why the occurrence of lower organic matter in
the cultivated areas is observed.

Also, a significant variation between treat-
ments was observed for the available phosphorus (P)
which was found to be slightly higher in the newly
cultivated areas (table 21).

From the above tables it is clear that, the natural
fertility of the soils; particularly the presence of
nitrogen (N), phosphorus (P) and organic matter; is
low and generally decrease with the increased period
of cropping.

Another test was carried to determine the level
of sodium absorption ratio (SAR). Table 24 indicates
that a highly significant change occur between the
treatments for SAR. It is found that SAR is more in
old cultivated areas. This increase is expected to
result in poor water infiltration, poor soil aeration
and increase osmotic pressure.

The statistical test for the soil pH indicates
that a significant variation was observed between
Table 23: Statistical analysis for the available phosphorus (P) in soils of the selected area.

a) Analysis of variance (ANOVA Table)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>Obs. F</th>
<th>Tabular F</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>4.36</td>
<td>2</td>
<td>2.13</td>
<td>12.996*</td>
<td>5.35</td>
<td>2.51</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>0.56</td>
<td>27</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.93</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) LSD Test of Significance:

<table>
<thead>
<tr>
<th>Treatments Mean</th>
<th>ST error</th>
<th>Difference between treatment means</th>
<th>LSD</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.05</td>
<td>T1-T2 = 0.39</td>
<td>0.26576</td>
<td>0.36023</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.66</td>
<td>T1-T3 = 0.93</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3.12</td>
<td>T2-T3 = 0.54</td>
<td>0.26576</td>
<td>0.36023</td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean = 2.61
Table 24: Statistical analysis of the S/F in soils of the selected area:

a) Analysis of variance (ANOVA table):

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>96.5</td>
<td>2</td>
<td>49.25</td>
<td>35.562</td>
<td>5.25</td>
<td>2.51</td>
</tr>
<tr>
<td>Residual</td>
<td>27.41</td>
<td>27</td>
<td>1.39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>123.92</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) LSD Test for Significance:

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean</th>
<th>ST. error</th>
<th>Difference between treatments means</th>
<th>LSD 5%</th>
<th>LSD 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.31</td>
<td>0.37</td>
<td>-0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>0.37</td>
<td>-0.06</td>
<td>0.75924</td>
<td>1.0252</td>
</tr>
<tr>
<td>3</td>
<td>6.39</td>
<td>0.37</td>
<td>-3.57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall mean = 3.82
treatments as shown in table 25. Compared with the controlled area, a high pH value was observed in the old cultivated area. The increase of soil pH was found to influence the nutrient absorption indirectly through its influence on nutrient availability. According to Brady 1974 who found that as the pH increases from 5.0 to 7.5 or 8.0 some of the essential elements tend to become less available.

From all of the above it is clear that there was a general decrease in the nutrients essential for crops with increased duration of cropping, indicating a decline in soil fertility. In fact decline in soil fertility is the main reason behind abandoning schemes (table 26). Loss of soil fertility is clearly known to farmers by the appearance of certain types of weeds such as 'kamba' Amaranthus and 'odor' Cowpea. These types of weeds are associated with monocropping of maize which occupied about 88 per cent of the total area under cultivation in the district.

Dure crop is very exhaustive to the soil fertility, especially when it is cultivated continuously. The situation is further worsened taking into consideration that fertilizers are not used in the area to
Table: 25) **Statistical analysis for pH and soils of the selected areas**

**c) Analysis of variance (ANOVA Table)**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>0.56</td>
<td>2</td>
<td>0.28</td>
<td>4.35</td>
<td>2.51</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>2.62</td>
<td>27</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3.18</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**b) LSD Test for Significance**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean</th>
<th>S.E.</th>
<th>Difference Difference</th>
<th>LSD 5%</th>
<th>LSD 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.2</td>
<td>0.1</td>
<td>T₁-T₂ = 0.35</td>
<td>0.2053</td>
<td>0.2771</td>
</tr>
<tr>
<td>2</td>
<td>7.55</td>
<td>0.1</td>
<td>T₁-T₃ = 1.27**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.17</td>
<td>0.1</td>
<td>T₂-T₃ = 0.92**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean = 7.74.
Table: 26) Shown reasons behind adoption scheme in the district and the % of respondent to each reason:

<table>
<thead>
<tr>
<th>Reason</th>
<th>% of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- loss of soil fertility</td>
<td>42</td>
</tr>
<tr>
<td>2- run off</td>
<td>22</td>
</tr>
<tr>
<td>3- location of schemes adjacent to residential routes</td>
<td>10</td>
</tr>
<tr>
<td>4- remoteness of the scheme</td>
<td>3</td>
</tr>
<tr>
<td>5- problems of drinking water</td>
<td>6</td>
</tr>
<tr>
<td>6- others</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field work data, 1984.
Table: 27) Reasons for drop in yields of crops in the district:

<table>
<thead>
<tr>
<th>Reasons</th>
<th>% of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Inadequate rainfall</td>
<td>90</td>
</tr>
<tr>
<td>2- Bad management practices</td>
<td>30</td>
</tr>
<tr>
<td>3- Prevalence of pests and diseases</td>
<td>32</td>
</tr>
<tr>
<td>4- Shortage of fuel and spare parts</td>
<td>23</td>
</tr>
<tr>
<td>5- Shortage of drinking water</td>
<td>11</td>
</tr>
<tr>
<td>6- Shortage of labour</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: Respondents mentioned more than one answer.

Source: Field work data, 1984.
support this extractive type of agriculture and crop rotation is not followed. It is found that about 30 per cent of the farmers leave part of the plots uncultivated and only when they feel that it is no longer fertile to support a good stand of crop. The reasons behind not following the recommended crop rotation suggested by the N.P.S. as indicated by farmers reflect lack of technical know how, inadequate rainfall and high costs of production (table 27).

5.5.4 Drop in yield per fodder

It may be stated that unless food production is highly threatened then there is no soil degradation. Farmers in the area are aware of the drop in yields of the different crops. About 72 per cent of the respondents perceived this reduction at least in the last few years. In order to determine the factors behind drop in yields per fodder a computer model was used (Appendix 4) testing the variation in yields of sorghum (dependent variable) measured against area under cultivation and total rainfall (independent variables). The results are shown in a correlation matrix. Note that for the three computer models:

X-1 stands for total yield
X-2 stands for total area
X-3 stands for total rainfall.

The correlation matrix for the three models is displayed by the table below:

<table>
<thead>
<tr>
<th></th>
<th>X-1</th>
<th>X-2</th>
<th>X-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-1</td>
<td>1.000</td>
<td>0.311</td>
<td>0.276</td>
</tr>
<tr>
<td>X-2</td>
<td>0.311</td>
<td>1.000</td>
<td>0.335</td>
</tr>
<tr>
<td>X-3</td>
<td>0.276</td>
<td>0.335</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Note: This relation is held constant in the three computer models.

**Reporting the results:**

**Test of significance:**

Recalling equation (1) the results of the T-test is as follows:

\[ X_1 = 634.37 + 0.0401X_2 + 49.59X_3 \]

Theoretical \[ T = 105 = 1.703 \]

Observed \( T = 2.771 \)

\( \frac{15}{15} = 2.773 \)

(0.23)(1.25)(1.02)

* insignificant at 10% level of significance

** insignificant at 5% level of significance.
insignificant at 0.5% level of significance.

Multiple correlation R = 0.906

Computer model No. 2:

Recalling equation (1) the result is as follows with T-stat.

\[ X_2 = 3.225.234 + 0.05503X_1 \]

T. stat = (5.32) (1.73)

Theoretical T = 10% = 1.281 5% = 2.467

0.5% = 2.763

R = 0.906

Computer model No. 3:

Recalling the same equation

\[ X_3 = 612.0 + 5020 + 70.67(9000X_1) \]

T. stat = (0.01) (1.52)

R = 0.903

Comments:

On multiple correlation a high coefficient is obtained between the dependent variable (yield) and the other two independent variables (total area and total annual rainfall) in the order 0.909, 0.906 and 0.903 which means that there is a close association between these variables.

Although there is a positive correlation between
the variables yet, the correlation matrix between the total yield and the total area is low (0.311) and more lower between yield and total annual rainfall (0.275). This implies that increase or decrease in the total yield is not necessarily brought about by the increase or decrease in total area and total rainfall. Other factors are contributing significantly to the variation in yield. These include soil fertility, the distribution of rainfall within the growing season rather than the total amount, the infiltration rate of rain water which proved to be decreasing with continuous shallow plowing and other management practices such as crop rotations, shelter belts, long fallow periods... etc. These management practices are important factors in maintaining soil fertility and hence obtaining good yields.

Fig. 13, 14, and 15 show the declining productivity of the major crops in the districts. From these figures it is clear that while there was steady increase in the area put under production, the yield per feddan was steadily decreasing given that the total annual rainfall was fluctuating around the total annual mean. This supports the fact that other factors are
contributing significantly to the drop in yield which the district witnessed in the last few decades. The important factor may be degradation of soil texture, structure and fertility.

Farmers in the area are aware of this drop in yield. Several reasons were thought behind this drop in yield. These include: inadequate rainfall, bad management practices, incidence of pests and diseases, lack of extension services ... etc. Table 26 gives the reasons stated by farmers as contributing to the drop in yield. All the stated factors revolve around mismanagement and negligence of proper conservation practices which led to wide scale degradation.

From what has been discussed in this chapter, it is becoming obvious that there are conflicts between national and regional interests, conflicts between different departments of natural resources at the district level, absence of institutional control and lack of proper conservation measures towards natural resources among scheme owners in the district. The ultimate result has been mismanagement of natural resources and desertification in the district which manifested in the overgrowth of mangroves, deforestation, soil degradation, declining productivity and hence
degradation of human environment. Thus the hypotheses stated in chapter III are upheld.
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions:

This study reveals that environment and natural resources in the Sudan had been degraded and managed in a most irrational and unconservational manner. The result of this had been indiscriminate destruction of forests and other woodlands, depletion of wildlife, destruction of rangelands through overgrazing, soil degradation and erosion, drop in yields and consequently desertification of large arable lands as seen in the Gedaref district.

This management of natural resources resulted from:

1) Lack of clear environmental policy to provide a base for positive and concrete actions. To this is the lack of unified, definable land-use policy. Instead these are piecemeal policies dealing with wide range of interests e.g. Forest Policy, M.E.C. Policy, Wildlife Policy ... etc.
2) Inadequate consideration of the environment and natural resources in planning process. All development plans since Independence did not contain any section on environment and resource management. This is clear in the priorities of the Ministry of Agriculture which put the natural resources at the bottom of the list. Meanwhile more emphasis had been given to the activities which degraded the environment such as horizontal expansion of mechanized rainfed agriculture and application of fertilizers and pesticides.

3) The absence of co-ordinating structure to organise the work of the ministries and departments involved in environment and natural resource management. This resulted in some departments being engaged in activities which often prejudicial to the work of other units. Also, due to this lack of co-ordination and division of responsibilities the institutional response to natural resource degradation is being fragmentary and largely ineffective.

4) The absence of legislative support to deal with environmental issues in totality. All
Legislations present belong to individual sectors such as Forest Acts of 1932, Environmental Health Act of 1975, ... etc. Even these sectors with laws and regulations, the study found the lack of will to implement these rules.

6.2. Recommendations:

For better rational use of the environmental resources available and in order to reverse the trend of degradations, the following are recommended:

1) Institutional framework for environmental management.

It is highly recommended to establish an institutional structure e.g., National Environmental Council, Fig. 16 for:

1) The sound assessment of natural and human resources,

ii) The formulation, planning, promotion, implementation, co-ordination and monitoring of environmental policies.
iii) The review and evaluation of the effects of such policies.

The proposed structure should satisfy the following:

i) Be given the mandate directly from the President and should involve those responsible for environment and resource management.

ii) Supported by the appropriate legislative mechanisms.

iii) Have to overcome interministerial and institutional differences and become the real guardian of the nation's resource base.

iv) Have real strength and efficiency to establish good horizontal linkages and really involve people in the field.

iv) Have representatives at the regions, districts and villages to be aligned with the decentralization achieved in the ministry to ensure co-ordination and involvement of the local people in order to be aware of the ecological consequences of their activities.

2) Environmental Laws and Legislations:

To ensure that the proposed structure satisfy its objectives, a unified comprehensive environmental
law is recommended. This law should be management-oriented, based on environmental criteria.

Legislation concerning environmental planning, perpetuity of the natural environment and regulations concerning its implementation and management procedure need be determined in order to define the responsibility and authority for the management of the environment and natural resources.

Also, activities concerning the development of legislation must be followed by the development of suitable legal controls.

3) Environmental Education and Training:

In order that a full understanding of the objectives of the proposed structure is attained and citizens be aware of their environment, it is recommended that environmental education skills and training programmes be provided in each sector and level of development planning and implementation. This is needed for educating and training people in management of natural resources and the environment, in particular planners of projects in all fields of activities. Education classes should be included in the curriculum of
schools at all levels to motivate the youth to work together to save the environment. Participation of the mass media and other information services in environmental affairs to be further developed.
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APPENDIX I

Legislative text dealing with water supply, water use and water quality.

1) The public Ferry Ordinance, 1939.
2) The Nile Ferry Control Ordinance, 1939.
3) The Nile Pumps Control (General Regulations), 1951.
4) The Nile Pumps Control (Stand-by) Regulations, 1953.
5) The Nile Pumps Control (General Amendment No. 2) Regulations, 1963.
8) The Freshwater Fisheries Ordinance, 1954.
14) The Environmental Health Act, 1975.
Questionnaire 2/A

Environmental Management in Salon for fishers

(Projects - askers)

1- Name of the department/Institution
2- The main sections of the department
3- State the main activities of your department
4- State the policy of the department concerning resource management and environmental conservation.
5- Are there any activities/project carried by your dept. with respect to resource management?
6- What are the objective of these activities/projects?
7- Do you think these projects satisfied their objectives?
   A) Yes
   B) No
8- If No, why they did not satisfy their objectives?
9- Could these factors be evaded in order that the projects satisfy their objectives?
10- Are there any projects specifically designed to address environmental and resource degradation illfa?
    A) Yes
    B) No
11- If yes what kind of projects?
12- In the last 6-Year Development Plan (1977/78-1982/83) are there any projects carried out by your department which is environmentally assessed
before implementation?
A) Yes  B) No

13- If yes .... What are these ??

14- If No .. Why?

15- What are the main problems facing the implementation of the projects carried out by your department?

16- Do you feel that BIA of projects is necessary?

17- Is there any co-ordination between your department and the other departments concerned with natural resources?
A) Yes  B) No

18- If you how Co-ordination is done?

19- If No, why?

20- If No, are there any environmental problems which can be attributed to this lack of co-ordination? Give examples if possible.

21- What do you recommend to achieve co-ordination between your dept. and others?

22- Are there any regulations or laws set by your dept. aiming at regulating resources use?
A) Yes  B) No

23- If yes, what are these ??
24.- How these laws or regulations are implemented?
25.- Are you satisfied with the level of implementation?
26.- If not satisfied, how to improve it?
27.- Do you think these laws and regulations are satisfactory... why?
28.- If No, why?
29.- If No, what kind of laws do you recommend?
30.- The regulatory measures of natural resources management have been affected one piecemeal basis, to what extent do you think this statement is true?
APPENDIX "2(3)

Resource Management in Central District
Questionnaire for Farmers.

Social
1. Name
2. Age
3. Level of education
4. Occupation
5. Resident or migrant
6. If migrant, from where did you come?
7. Why you come to this area.

Management Practices:
1. Land tenure
2. Size of farm
   01. Less than 500 faddans
   02. 500 - 1000 faddans
   03. 1000 - 2000 faddans
   04. More than 2000 faddans
3. For how long did you cultivate this farm
   01. Less than 5 years
   02. 6-10 years
   03. 11-15 years
   04. 16-20 years
<table>
<thead>
<tr>
<th>Question</th>
<th>01</th>
<th>02</th>
<th>03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you got a farm before?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>If yes, why did you quit to this farm?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of soil &amp; fertility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run off problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problems of drinking water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un accessibility of roads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What types of machinery use to prepare the land?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there any problems arising from using this type of machinery?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Don't know</td>
</tr>
<tr>
<td>How can you get rid of the previous crop residue?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allow animals to graze</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut and packed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digging and mulching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you allow the moose to graze the crop residues?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Do you suffer from invasions by the moose of this or adjacent areas?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
11- Do you think that crop rotation is important?
   01- Yes  02- No  03- I don't know

12- Do you practice crop rotation?
   01- Yes  02- No

13- If yes, what type of crops do you rotate?
   01- If no, Why?
     01- High costs of production
     02- Inadequate rainfall
     03- Lack of technical know how
     04- Others

15- Are there any considerations with respect to:
   1) Using certified seeds?
     01- Yes  02- No
   2) Applying fertilizers?
     01- Yes  02- No
   3) Mulching crop residues?
     01- Yes  02- No
   4) Using pesticides?
     01- Yes  02- No

16- Are there any recommendations offered to you with respect to:
   1) Afforestation?
     01- Yes  02- No
   2) Wind breaks?
     01- Yes  02- No
   3) Shelter belts?
     01- Yes  02- No
17- Have you followed these recommendations?
   01- Yes  02- No
18- If yes, are they useful?
   01- Yes  02- No
19- If no, Why?
   01- Trees will compete crop for water
   02- Trees attract birds
   03- Trees hinder mechanized operations
   04- Trees will reduce area that can be used for crops
   05- Others
20- Do you notice any change in yield during the previous 3 or 4 years?
   01- Yes  02- No
   01- High
   02- Medium
   03- Low
   04- Same
22- In your opinion what are the reasons behind good yields?
   01- Adequate rainfall
   02- Good management practices
03- Availability of drinking water
04- Availability of fuel and spare parts
05- Availability of labours
06- Others

23- In your opinion what are the reasons behind bad yields?
01- Inadequate rainfall
02- Prevalence of pests
03- Shortage of drinking water
04- Shortage of fuel and spare parts
05- Shortage of labour
06- Bad management practices
07- Others

24- During cultivation do you observe degradation in the nature of soil?
01- Yes
02- No

25- What are the signs of degradation?
01- More frequent of dust storms
02- Increase in areas of bad land
03- Appearance of new khasis
04- Runoff
05- Others

26- What have done about the soil degradation?
01- Nothing
02- Crop rotation
03- Mulching
04- Terracing
05- Others

27- Do you receive any technical assistance from the Mechanical Crop Production Corporation (M.C.P.C.) members with respect to the problem of Soil degradation?
01- Yes ( ) 02- No ( )

28- Would you willingly participate or pay in Soil conservation projects?
01- Yes ( ) 02- No ( )

Rainfall

1- How do you rate the amount of rainfall in relation to cultivation in each of the following years?

<table>
<thead>
<tr>
<th>Year</th>
<th>Adequate</th>
<th>Insufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>( )</td>
<td>(            )</td>
</tr>
<tr>
<td>1982</td>
<td>( )</td>
<td>(            )</td>
</tr>
<tr>
<td>1981</td>
<td>( )</td>
<td>(            )</td>
</tr>
<tr>
<td>1980</td>
<td>( )</td>
<td>(            )</td>
</tr>
</tbody>
</table>

2- How do you rate the amount of rainfall in the following years?

<table>
<thead>
<tr>
<th>Year</th>
<th>Adequate</th>
<th>Insufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>( )</td>
<td>(            )</td>
</tr>
</tbody>
</table>
1982 ( ) ( )
1981 ( ) ( )
1960 ( ) ( )

3- In your opinion what are the results of inadequate rainfall.
   1- Crop failure ( )
   2- Inefficient pasture ( )
   3- Death of trees ( )
   4- High livestock mortality ( )
   5- Others

Vegetations:
1- What are the main tree species existing at present?
2- Please mention other tree species which were prevailing in the past but disappearing?
3- What are the main grass species existing at present?
4- Please mention other grass species prevailing in the past but no longer existing?
5- When did the mention tree and grass species begin to disappear?
   1- Tree species
   2- Grass species

6- In your opinion what are the reasons behind the disappearance of tree species you mentioned?

7- In your opinion what are the reasons behind the disappearance of grass species you mentioned?
9- Did you observe any new tree species in the area?
   1- Yes ( )  2- No ( )

10- What are these species?

11- Have you observed any new grass species in the area?
   1- Yes ( )  2- No ( )

12- What are these species?

13- How do you rate the new tree species compared to the once prevailing ones?
   1- Better ( )
   2- Same ( )
   3- Inferior ( )

14- How do you rate the new grass species to the once prevailing ones?
   1- Better ( )
   2- Same ( )
   3- Inferior ( )

15- Have you observed any change in tree vegetation cover in the area?
   1- Increased ( )
   2- Decreased ( )
   3- No change ( )

16- Have you observed any change in grass vegetation
Cover in the area

1. Increased ( )
2. Decreased ( )
3. No change ( )

**Comment**

1. Please list grass species preferred by animals but are no longer existing?

2. When did these species disappear from the area?
   1. 4-5 years ago ( )
   2. 6-10 " " ( )
   3. 11-15 " " ( )

3. In your opinion what are the reasons behind the disappearance of these species?

4. How do usually obtain free fodder?
   1. Collect or cut grass ( )
   2. Fell trees ( )
   3. Cut branches ( )
   4. Buds and fruits ( )
   5. Fallen leaves ( )
   6. St re crop residues ( )
   7. Others ( )

5. Do you obtain hay for your animals to be consumed in village?
   1. Yes ( )
   2. No ( )
6- How do you obtain hay?
   1- Collect by family members
   2- Buy

7- Apart from hay, do you give supplementary feed to your livestock?
   1- Yes ( )
   2- No ( )

8- If yes, which of the following do you give?
   1- Crop residues ( )
   2- Korma ( )
   3- Cotton seeds ( )
   4- Cokes ( )
   5- Others ( )

9- In your opinion when did people begin to use supplementary feed?

10- Which are the most critical months for fodder shortage in the area?

Fuel:

1- Which of the following materials do you use at home?
   1- Wood ( )
   2- Charcoal ( )
   3- Kerosene ( )
   4- Crop residues ( )
   5- Dyes ( )
   6- Others ( )
2- How do you obtain the following materials?

<table>
<thead>
<tr>
<th></th>
<th>Collect</th>
<th>Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Wood</td>
<td>(</td>
<td>(</td>
</tr>
<tr>
<td>2- Charcoal</td>
<td>(</td>
<td>(</td>
</tr>
<tr>
<td>3- Grass</td>
<td>(</td>
<td>(</td>
</tr>
</tbody>
</table>

3- What tree species do you use at present for fuel?
- Wood
- Charcoal

4- What tree species did you use in the past that are no longer existent?
- Wood
- Charcoal

5- From where do you obtain fuel?

<table>
<thead>
<tr>
<th></th>
<th>Immediate Vicinity</th>
<th>Distant Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>(</td>
<td>(</td>
</tr>
<tr>
<td>Charcoal</td>
<td>(</td>
<td>(</td>
</tr>
</tbody>
</table>

6- What is the average amount of wood do you consume monthly?

7- Do you think that any degradation has taken place in the vegetation?
   1- Yes (       )
   2- No (       )

8- If yes, What are the reasons behind this degradation?
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Increase in number of animals</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Impact of water source</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Expansion of cultivation</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Commercial production of fuel wood and charcoal</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Impact of nomads</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1: Shows the yield of sorghum (Bursa) in relation to total area and total rainfall in the GahND District in the period (1954 - 1963)

<table>
<thead>
<tr>
<th>Season</th>
<th>Total Area (Ha)</th>
<th>Total Yield (Tons)</th>
<th>Total Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954/55</td>
<td>250,000</td>
<td>60,000</td>
<td>557.00</td>
</tr>
<tr>
<td>1955/56</td>
<td>300,000</td>
<td>150,000</td>
<td>586.70</td>
</tr>
<tr>
<td>1956/57</td>
<td>671,863</td>
<td>335,332</td>
<td>696.98</td>
</tr>
<tr>
<td>1957/58</td>
<td>872,000</td>
<td>413,415</td>
<td>616.90</td>
</tr>
<tr>
<td>1958/59</td>
<td>637,907</td>
<td>392,059</td>
<td>471.70</td>
</tr>
<tr>
<td>1959/60</td>
<td>901,192</td>
<td>675,560</td>
<td>558.60</td>
</tr>
<tr>
<td>1960/61</td>
<td>622,700</td>
<td>131,348</td>
<td>430.70</td>
</tr>
<tr>
<td>1961/62</td>
<td>874,345</td>
<td>453,503</td>
<td>599.90</td>
</tr>
<tr>
<td>1962/63</td>
<td>700,000</td>
<td>320,000</td>
<td>571.70</td>
</tr>
<tr>
<td>1963/64</td>
<td>765,631</td>
<td>233,459</td>
<td>763.30</td>
</tr>
<tr>
<td>1964/65</td>
<td>961,700</td>
<td>354,563</td>
<td>551.50</td>
</tr>
<tr>
<td>1965/66</td>
<td>892,775</td>
<td>371,323</td>
<td>623.30</td>
</tr>
<tr>
<td>1966/67</td>
<td>1,148,700</td>
<td>222,255</td>
<td>609.517</td>
</tr>
<tr>
<td>1967/68</td>
<td>1,634,495</td>
<td>636,643</td>
<td>662.50</td>
</tr>
<tr>
<td>1968/69</td>
<td>1,166,360</td>
<td>181,589</td>
<td>530.30</td>
</tr>
<tr>
<td>1969/70</td>
<td>1,319,676</td>
<td>314,956</td>
<td>451.20</td>
</tr>
<tr>
<td>1970/71</td>
<td>1,557,275</td>
<td>447,797</td>
<td>518.50</td>
</tr>
<tr>
<td>1971/72</td>
<td>1,375,700</td>
<td>427,302</td>
<td>473.70</td>
</tr>
<tr>
<td>Year</td>
<td>Amount</td>
<td>Rate</td>
<td>Total</td>
</tr>
<tr>
<td>-------</td>
<td>---------</td>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>1972/73</td>
<td>1,805,535</td>
<td>180.759</td>
<td>616.00</td>
</tr>
<tr>
<td>1973/74</td>
<td>1,261,000</td>
<td>391.412</td>
<td>598.20</td>
</tr>
<tr>
<td>1974/75</td>
<td>1,566,000</td>
<td>426.821</td>
<td>712.00</td>
</tr>
<tr>
<td>1975/76</td>
<td>1,999,445</td>
<td>796.710</td>
<td>606.80</td>
</tr>
<tr>
<td>1976/77</td>
<td>1,692,950</td>
<td>571.840</td>
<td>642.80</td>
</tr>
<tr>
<td>1977/78</td>
<td>1,347,610</td>
<td>461.300</td>
<td>608.00</td>
</tr>
<tr>
<td>1978/79</td>
<td>1,915,690</td>
<td>522.440</td>
<td>602.80</td>
</tr>
<tr>
<td>1979/80</td>
<td>2,000,000</td>
<td>545.440</td>
<td>775.30</td>
</tr>
<tr>
<td>1980/81</td>
<td>2,153,400</td>
<td>646.710</td>
<td>638.00</td>
</tr>
<tr>
<td>1981/82</td>
<td>2,030,650</td>
<td>1,070.720</td>
<td>624.00</td>
</tr>
<tr>
<td>1982/83</td>
<td>2,970,920</td>
<td>571.180</td>
<td>715.00</td>
</tr>
<tr>
<td>1983/84</td>
<td>3,032,630</td>
<td>456.950</td>
<td>482.00</td>
</tr>
</tbody>
</table>
4) First Computer Model:

The first computer model is confined to the study of variation in yields of sorghum (dependent), on explanatory basis of total area under cultivation and the total amounts of rainfall (independent variables). X-1, X-2 and X-3 stands for total yield, total area and total rainfall respectively.

The regression analysis for the first computer model is shown as follows:

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>X-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of Freedom</td>
<td>27</td>
</tr>
<tr>
<td>Independent variable at significant level</td>
<td>99.99%</td>
</tr>
<tr>
<td>Constant</td>
<td>X-2</td>
</tr>
<tr>
<td>----------</td>
<td>-----</td>
</tr>
<tr>
<td>X-1</td>
<td>X-2</td>
</tr>
<tr>
<td>Mean</td>
<td>62601.033</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>21436.420</td>
</tr>
</tbody>
</table>

1) Variables in the regression set

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Constant</th>
<th>R²</th>
<th>R²-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression coeff.</td>
<td>7343.3789</td>
<td>0.944013</td>
<td>49.5876</td>
</tr>
<tr>
<td>Standard error</td>
<td>201407.3-5</td>
<td>34717.2-1</td>
<td>4878752-2</td>
</tr>
<tr>
<td>T- Stat</td>
<td>0.23</td>
<td>1.29</td>
<td>1.02</td>
</tr>
<tr>
<td>Partial correlation</td>
<td>0.04</td>
<td>0.24</td>
<td>0.19</td>
</tr>
<tr>
<td>Multiple correlation</td>
<td>0.905</td>
<td>0.903</td>
<td>0.956</td>
</tr>
</tbody>
</table>
2) **Multiple Regression**

- **Estimated Regression Function:**
  
  The estimated regression function is given by:
  
  $$ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 $$  \( (1) \)

  
  Where:
  
  $$ \beta_0 = 6.033,370 \quad \beta_1 = 6.044013 \quad \beta_2 = 68.55278 \quad \beta_3 $$

- **Sum of Squares:**
  
  The error sum of squares (E.S.S.) has the equation:
  
  $$ \text{E.S.S.} = \sum (Y - \bar{Y})^2 $$  \( (2) \)

  The result is given above at 111032.

- **Coefficient of Multiple Determination:**
  
  The coefficient denoted usually as \( R^2 \) is defined as analogously to \( r^2 \) - the coefficient of simple determination:
  
  $$ R^2 = \frac{\text{SSTO} - \text{SSE}}{\text{SSTO}} $$

  The result is given as 0.906.

3) **Second Composite Model**

   This model confined to study the variation in yield (dependent variable), on the explanatory basis of total area (independent variable).

4) **Regression Analysis:**

   Dependent variable: \( X-1 \)
Degree of freedom 28
independent variables at significant level 39,396
Constant X=2

Variables in the regression set:

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Constant</th>
<th>X=2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reg. Coeff.</td>
<td>3.6255</td>
<td>0.056536</td>
</tr>
<tr>
<td>Standard error</td>
<td>619735</td>
<td>321332 E-1</td>
</tr>
<tr>
<td>T. Stat</td>
<td>5.52</td>
<td>1.73</td>
</tr>
<tr>
<td>E,St.</td>
<td>256139 E-11</td>
<td>-135865 E-11</td>
</tr>
<tr>
<td>Residual error</td>
<td>209252 E-5</td>
<td></td>
</tr>
<tr>
<td>Mult. Corr.</td>
<td>0.906</td>
<td></td>
</tr>
<tr>
<td>D. Waston D Stat</td>
<td>1.5729</td>
<td></td>
</tr>
</tbody>
</table>

(i) Estimated regression function:

Recalling equation (1) the estimated regression function

\[ Y = 3.6255 + 0.056536 X_2 \]

(ii) Analysis of variance sum of squares:

The error sum of squares is S.S.E.

which is

\[ S.S.E = \sum (Y - Y_1)^2 \] has a result of

256139 E-11
iv) The coefficient of multiple determination

\[
R^2 = \frac{SSR}{SSTO} = 1 - \frac{SSE}{SSTO}
\]

The result given is 0.906

c) **Third computer model:**

In this model we study the variation in yield (dependent variable) on the explanatory basis of total annual rainfall (independent variable).

1) **Regression analysis:**

Dependent variable: \( Y-1 \)

Degree of freedom: 20

Independent variable at significant level: 99.99%

Constant: \( X-3 \)

Variables in the regression set

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Constant</th>
<th>( X-3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reg. Coeff.</td>
<td>0.12,044502</td>
<td>70.674500</td>
</tr>
<tr>
<td>T. Stat</td>
<td>0.01</td>
<td>1.52</td>
</tr>
<tr>
<td>R.S.S.</td>
<td>125347 E-11</td>
<td>135680 E-11</td>
</tr>
<tr>
<td>Residual error</td>
<td>211501 E-5</td>
<td></td>
</tr>
<tr>
<td>Multiple corr.</td>
<td>0.303</td>
<td></td>
</tr>
</tbody>
</table>

Durbin-Watson D. Stat = 1.4931

ii) **Estimated regression function:**

Recalling equation 1, the estimated regression function is seen to be
\[ Y = 612.044502 + 70.674960 \, X_2 \]

iii) Analysis of variance sum of squares:

\[ \text{B.S.S.} = \sum (Y - \bar{Y})^2 \]

has a result of 125346.211.

iv) The coeff. of multiple determination:

\[ R^2 = \frac{\text{SSTR}}{\text{SSTC}} = 0.862 \]

The result is given as 0.862.