MONITORING DESERTIFICATION: (VEGETATION DEGRADATION) USING REMOTE SENSING AND GIS TECHNIQUES IN NORTH-WESTERN GEZIRA, SUDAN

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DEDICATION

To my Father and mother; my brothers and sisters; My husband Ibrahim and my friends who encouraged me to do this work, I dedicate this dissertation.
ACKNOWLEDGEMENT

Major thanks are due to those various institutions and individuals involved for their cooperation in completing this work.

First of all I would like to acknowledge my supervisor Dr, Amna Ahmed Hamid for generous, creative suggestions and valuable guidance.

Acknowledgement is given to the administrative staff of the Remote Sensing Authority, who has continuously provided the software and technical support in aid of this research.

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I gratefully acknowledged the support of The Civil aviation Authority for providing the transport for the fieldwork, particularly Mr. Panansio the driver who has kindly join us and Hanan Mahmood for her technical assistance.

Mr. Jabber Babikrk’s family, Mr. Ahmed Abdalla and Mr. Babikr Ahmed Babikr and my friend Um salma Osman were provided a comfortable accommodation and reception in their home in Elgetienia city to conduct the fieldwork.

In addition I wish to express my thanks to Mr. Ibrahim Eldaai and his family for hosting me during the examination periods.

Finally I greatfully acknowledged the interest shown and encouragement given by my husband Ibrahim Habila Osman during this dissertation.
ABSTRACT

This study has been conducted in the area between the northwestern part of Gezira Agricultural Scheme and the White Nile to study the problem of desertification as general with the emphasis on vegetation cover degradation.

The aim of the dissertation is the focusing on the use of Remote Sensing and Geographic Information Systems technologies as an integrated tool to monitor vegetation cover degradation.

The product of interpretation of Landsat Thematic Mapper image (1996) was compared with vegetation map of Harrison & Jackson (1958) to calculate the changes in the vegetation areas as result of desertification. This was verified by fieldwork.

Mapping of the land use was made to show the entrance of man and his animal as causes of desertification.

Suggestions was made to use Advance Very high Resolution Radiometer data and Normalized Difference Vegetation Index (NDVI) over a series of time for more repetitive vegetation cover degradation, to calculate risk and rate at which degradation occur.

Remote Sensing and Geographic Information systems can be used to monitor desertification in other affected states of the country.
الخلاصة

اجرت هذه الدراسة في المنطقة الواقعة بين النيل الأبيض والجهة الغربية لمشروع الجزيرة الزراعي وخطي عرض 14°-15 شماليًا، بهدف استخدام تقنيي الاستشعار عن بعد ونظم المعلومات الجغرافية لرصد ظاهرة التصحر بصورة عامة ومتابعة تدهور الغطاء النباتي بصفة خاصة.


اعدت الدراسة تخريطة لاستخدامات الأراضي في هذه المنطقة مبينة بالمساحات كمؤشر لتدخل الإنسان والحيوان في تسبب ظاهرة التصحر.

اقترحت في التوصيات استخدام صور الإقمار الصناعية NOOA (والتي تحمل المتحسس) والتي تحمل التنكس AVHRR (وإذا استخدم دالة تنوع خضرار النباتات NDVI) لفترة من الزمن للتقدير التكراري لحالة الغطاء النباتي ومعدل حركة تدهوره.

ابنت الدراسة امكانيه استخدام تقنيي الاستشعار عن بعد ونظم المعلومات الجغرافية لاحتمال التصحر في بقية أقاليم المتاثرة في السودان.
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<thead>
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<th>Description</th>
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<tr>
<td>ASALs</td>
<td>Arid and Semi-Arid Lands</td>
</tr>
<tr>
<td>AVHRR</td>
<td>Advance Very High-Resolution Radiometer</td>
</tr>
<tr>
<td>ERTS</td>
<td>Earth Resource Technology Satellites</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FCC</td>
<td>False Color Composite</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GOES</td>
<td>Geostationary Operational Environmental Satellites</td>
</tr>
<tr>
<td>INCD</td>
<td>Inter-governmental Negotiating Committee</td>
</tr>
<tr>
<td>MSS</td>
<td>Multi-Spectral Scanner</td>
</tr>
<tr>
<td>NDDU</td>
<td>National Drought and Desertification Coordinating Unit</td>
</tr>
<tr>
<td></td>
<td>(National focal point for the UNCCD)</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NDVI</td>
<td>Normalized Difference Vegetation Index</td>
</tr>
<tr>
<td>NGOs</td>
<td>Non-governmental Organizations</td>
</tr>
<tr>
<td>P/PET</td>
<td>Precipitation (P) over Potential Evapotranspiration (PET)</td>
</tr>
<tr>
<td>PACD</td>
<td>Plan of Action to Combat Desertification</td>
</tr>
<tr>
<td>RBV</td>
<td>Return Beam Vidicon</td>
</tr>
<tr>
<td>TM</td>
<td>Thematic Map per</td>
</tr>
<tr>
<td>TIROS</td>
<td>Television Infra-Red Observation Satellites</td>
</tr>
<tr>
<td>UNCCD</td>
<td>United Nations Convention to Combat Desertification</td>
</tr>
<tr>
<td>UNCOD</td>
<td>United Nations Conference On Desertification</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UNSO</td>
<td>United Nations Sudan-Sahelian Office</td>
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CHAPTER ONE

1.1. Introduction

Desertification is a world phenomenon of degradation of the world’s ecosystems. It does not concern natural desert, and can only occur on land, which is vulnerable to desertification process. Vulnerability depends on climate, on its topography, the natural vegetation, and the most important, on the way resources are used by human communities. The total area of drylands affected by desertification is 3.6 billion hectares or about 70% of all agriculturally used dryland is affected to some degree by various forms of land degradation, mostly by the degradation of natural vegetation partly accompanied by serious degradation of soil (UNEP, 1992).

The main cause of the various forms of ecological degradation results from a combination of:
*Ecological condition that can be the inherent ecological fragility of the resource system and adverse climatic conditions.
*Human condition and factors, which can be manifested through the exploitation of water, soil and vegetation resources such as overgrazing, overcultivation, deforestation and irrigation mismanagement.

Desertification is further exacerbated by frequent drought in one or other arid or semi-arid zone in Africa as reported by Darkoh (1994). There are five principle processes of desertification: Vegetation degradation, water erosion, wind erosion, salinization and water logging and soil crusting and compaction. Desertification in arid and semi-arid regions often lead to the expansion of arid areas or alter the configuration of their boundaries as stated by Baban (2000). So mapping these changes and causes of desertification by traditional procedures is a time and cost consuming.

The United Nations Convention to Combat Desertification (UNCCD, 1994) recommends the creation of a monitoring system as well as the utilization and adoption of sciences and technologies for combating desertification. It is important to provide techniques to assist the identification of area potential desertification due to related causative factors.
Remote sensing data and Geographic Information System (GIS) data becomes a proper means for identifying areas affected by desertification. Remote sensing and GIS can also forecast, update and simulate various management schemes and provide information for the decision making process as reported by Baban (2000).

The use of remote sensing data and GIS techniques to detect the changes in the vegetation cover for monitoring desertification, is the major goal for this study. The information will help in planning for corrective measures to combat desertification.

1.2. Problem statement
1.2.1. Desertification problem

Over the last four decades in Sudan, desertification and drought prone areas has been accelerating at a faster rate and leading to marginalization and loss of arable land. According to (NDDU, 1999) the estimation of the utilization of the agroecological zones in 1990 is as follow: Desert (171.01 million of fedans), Cultivated area recently (18.5 million of fedans), Agricultural land (121.5 million of fedans), Natural pasture (221 million of fedans). In such vast areas, desertification monitoring is performed on the ground by observing some selected land surface parameters, such as vegetation density, types, development, biodiversity, soil conditions. However, it is neither practically nor economically conceivable to monitor systematically the vast country area, by field investigations only, therefore remote sensing and GIS techniques are the most appropriate when having to deal with monitoring large areas.

1.2.2. Selection of the study area:

The Northwestern Gezira (Fig 1.1) considered as the western boundaries of irrigated Gezira Scheme of the Sudan, which is the largest one in Sudan. Some of the White Nile schemes included in this study area,
and the man and his livestock depend largely on the natural vegetation. In this area some researches has been started in the field of land degradation and sand encroachment in general, for example, (Obeid et al., 1982). Also (Fadul et al., 2000) conducted a research on sand encroachment and land degradation. In the same study area also another research was done by Alamin (1999). But these researches did not emphasize the aspect of changes and degradation of the vegetation cover and did not use the remote sensing and GIS data as integrated tool for monitoring the vegetation degradation.
1.3. Objectives

The general objective of this study is to use the remote sensing data and GIS techniques as integrated tool for monitoring the vegetation cover degradation and desertification status in North-western Gezira. The specific objectives of this study are:

To map the changes in the vegetation cover between the period from 1958 to 2002 in North-western Gezira.

To demonstrate the suitability of remote sensing data and GIS techniques for as improved monitoring and assessment of desertification problems.

To provide a methodology on desertification monitoring that can be transferred to other parts of the Sudan.

1.4. Hypothesis

To achieve the objectives of the study, the following hypotheses are put for testing:
The vegetation cover of the area under consideration has been greatly degraded and destroyed due to uncontrolled exploitation of trees, shrubs, grasses and herbs of the study area.

The status of desertification can be detected and mapped using remote sensing and GIS techniques.

1.5. Justifications

The people of this area depend entirely on the natural vegetation for their livelihood as they are mainly farmers and livestock holders as well as they depend on it for their energy consumption, house construction and local industries.

The vulnerability to degradation and sand encroachment of this area call for monitoring of desertification.

Availability of remote sensing and GIS as promising techniques and operations to be used in large areas.

1.6. Materials and methods

1.6.1. Materials


Topographic map of El Geteina at scale 1:250000 produced in 1930s by Survey Department, Khartoum.


Computers, digitizer, scanner, and accessories to enhance mapping were used.
Global Positioning System (GPS) Garmin 12.

GIS software includes ARC/INFO Version 4.0 and Arc View Version 4.0 and Academic Ilwis 3.0.

Materials collected from the field.

1.6.2. Methods
1.6.2.1. Remote sensing method:
   The main method used was the interpretation of satellite image supported by fieldwork to verify the mapping units.

   Visual interpretation procedure was used based on the principle that different vegetation density have different spectral properties and, consequently, reflect electromagnetic energy received from the sun with different intensity within different wavelength bands in the electromagnetic spectrum.

   Use of existing 1:250000 scale topographic map of the study area to provide the boundaries, main features, villages and roads.

1.6.2.2. GIS method
   GIS facilities help to integrate various information layers and to present results, two GIS software used were:
   ILWIS software: was used for data editing and analysis.
   Arc/View: was used to manage data.
   The vegetation map of Harrison & Jackson (1958) was scanned and converted to digital formats.


   The two maps of the two periods (1958) and (2002) were overlaid by crossing to provide the comparison process.

   Three 60km long transects were made randomly across the area to representing the different mapping units.
Secondary data were collected from published works

1.6.2.3. Field checks

Sample plots were selected randomly using GPS for field checking and the data about the range, forest, land use and soil have been collected. Visual correlation was obtained between ground features and colour, tones, shown on the image.

1.6.2.4. Group discussion

Discussion was made with the village leaders, farmers, women and regarding the types and quantities of the natural vegetation, and use of trees, types of crops grown, and effects of desertification.

CHAPTER TWO
LITERATURE REVIEW

2.1. Desertification and land degradation

United Nations Conference on Environment and Development (UNCED, 1992) accepted the last internationally negotiated definition of
desertification. All participating governments approved Agenda 21, which defines desertification as

“Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.” Which was adopted by (UNCCD, 1994). Land and degradations were defined as land in this concept includes soil and local water resources, land surface and vegetation and crops. Degradation implies reduction of resource potential one or a combination of processes acting on the land. These processes include water erosion, wind erosion, and sedimentation by those agents, long-term reduction in the amount or diversity of natural vegetation, where relevant, and salinization and sodication (UNEP, 1992).

Aridity zones were defined in accordance with their physical parameters using the following ratio of Precipitation (P) over Potential Evapotranspiration (PET) (calculated by an adaptation of the Thornthwaite formula P/PET) as follow:

<table>
<thead>
<tr>
<th>Aridity Zone</th>
<th>Ratio of P/PET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyper-arid</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Arid</td>
<td>0.05 – .20</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>0.21 – 0.50</td>
</tr>
<tr>
<td>Dry Sub-humid</td>
<td>.51 – .65</td>
</tr>
<tr>
<td>Moist sub-humid</td>
<td>&gt;0.65</td>
</tr>
</tbody>
</table>

2.1.1. Processes of desertification

Processes of desertification include degradation of vegetation, water erosion; wind erosion; soil compaction and salinity/alkalinity and water logging.

2.1.2. Degradation of vegetation

Degradation of vegetation occur in the early stage of the desertification process, for example when deforestation makes soil more susceptible to wind and water erosion, but also continues later in response to the declines in soil fertility and structure that follows overcultivation, overgrazing and poor irrigation management. The vegetation cover of an area may be said to be degraded when it becomes inferior to:
(a) What the land could be expected to support, taking into account the climate, site conditions and historical experience;
(b) What the area needs for the purposes of environmental protection (Grainger, 1990).
*Forms of vegetation degradation:*

Degradation of vegetation takes two main forms

First form involves a reduction in the overall density of vegetation cover, as represented by the biomass (the amount of vegetative materials per unit area) and the proportion of the land covered by vegetation. This reduction takes place when trees are cleared for cropping and grazing, cut down for fuelwood or fodder or rangeland are overgrazed as reported by Grainger (1990).

Second form of degradation involves a change to a less productive type of vegetative cover, involving a modification in species composition, and possibly also in the general types of plants growing in an area. On overgrazed rangelands, for example, perennial grasses may be replaced by less palatable annual grasses and thorny stunted shrubs, both of which are characteristic of the less productive ecosystems of drier climates.

Both forms of vegetation degradation can also occur on overcultivated cropland. For example when the average density of vegetative cover falls owing to declining crop yields and shorter fallow periods, and (on irrigated croplands) when more saline-tolerant crop species have to be grown because of water logging and salinity problems (Grainger, 1990).

2.1.3. Causes of desertification

The climatic variations as the natural factors and human activities as active anthropogenic factors cause desertification as a complex phenomenon as Fallow:

2.1.3.1. Climatic variations

These include rainfall, humidity, wind and temperature.

2.1.3.2. Human activities

Four main types of poor land use cause desertification, they are overcultivation, overgrazing, deforestation and poor management of water holes.
2.1.3.3. Desertification and drought

In (UNCCD, 1994) drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. The drought cycle has stricken the Sudan-Sahelian countries since late 1960s and the early 1970s and from that time until now Sudan is suffering the long lasting imprints of drought disasters effects, desert encouchment and desertification impacts (Salih, 1996).

2.1.4. Consequences of desertification

Desertification has several consequences at local, national and global levels.

2.1.4.1. Global consequences
2.1.4.1.1. Environmental impacts

Desertification is an increasing element of planetary environmental degradation that plays a vital role in water, air, soil pollution, soil loss and climate change. It contributes heavily to loss of global biodiversity, particularly in the areas that are the centers of origin of major crop species of the world such as wheat, sorghum and maize (UNEP, 1992). It increases the loss of biomass and bioproductivity of the planet and exhaustion of the global humus reserve, thus disrupting normal global biogeochemical turnover and in particular, reducing the carbon dioxide sink (UNEP, 1992).

It contributes to global climate change by increasing the potential of such change and decreasing the current evapotranspiration rate, changing the ground surface energy budget and adjoining air temperature as well as adding dust and carbon dioxide to the atmosphere and this worsens the green house affect. Desertification directly reduces the world’s fresh water reserve.

2.1.4.1.2. Socio-economic impact
Desertification is the main cause of global loss of productive land resources and thus reduces the world’s capability to provide sufficient food and shelter to growing population (UNEP, 1992). It causes economic instability and political unrest in the affected areas, exacerbates the struggle for scarce land and water resources, and spurs outward migration in search of relief and refuge. It exerts enormous pressure on economy and stability of societies outside the affected areas by escalating need for food aid, as well as the influx of environmental refugees (UNEP, 1992). It prevents the achievement of sustainable development in the countries and regions affected and through them, the world as the whole. It directly threatens the health and nutrition status of the affected population particularly children (UNEP, 1992).

2.1.4.2. National and / or local impacts:
2.1.4.2.1. Ecological impacts include the following:

Change in the Soil status such as:
Accumulation of salts, formation of crust, degradation of soil structure, humus reduction (decrease in organic matter) soil regime (soil climates), water and moisture regime, temperature regime, gas regime.

Change in the status of local water resources such as:
Drying of lakes, lowering of the level of ground water, salinization of groundwater, increase of toxic components in groundwater.

Changes in the status of vegetation such as:
Reduction of amount and diversity of spices (xerophyization, halophytizion).

Change in the status of land surface like:
Formation of new dunes and reactivation of old fixed dunes, burying of fields, streets, roads, infrastructure, railways and settlements by sand.

2.1.4.2.2. Economic impacts
Lack of food and fodder, undernourishment, water shortages through miss management, disease and migration, deserted villages, inflated towns, unemployment, loss of identity, tribal conflicts and political strife (UNEP, 1992).
2.1.5. Desertification, its severity and efforts at global level:

Great number of people and millions of livestock animals died due to drought. The persistence and severity of the drought that first become evident in the Sahel region of West Africa in 1968 eventually altered the world attention to the importance of rainfall failure as a main cause of soil loss and ecological decline. In the early 1970s many people were impoverished, land in many parts of the world was degrading into desert, and desert does not produce food. The caring for natural resources and promoting their sustainable use is an essential response of the community to ensure their own survival. This was presented at the United Nations Conference on Human Environment, in Stockholm 1972 at which United Nations Environment Programme (UNEP) was established. Desertification as human environmental issue was first raised at that conference, and received very little attention and it was lumped together with many environmental problems.

One of the major issues the world community needed to address soon after the creation of (UNEP), was the land resources degradation, which endangered our basic production system. (UNEP) choose desertification and drought as a high priority area to fulfil its coordinating role. Therefore, United Nations Conference on Desertification (UNCOD) was convened in Nairobi in 1977. The main business of the conference was to discuss in detail “process and causes of desertification.” And “The plan of action to combat desertification (PACD).” In the main aims of plan of Action was the application of existing scientific and technological knowledge to halt desertification, reclaiming decertified lands and promoting the most effective and sustainable use of land vulnerable to desertification. It also stressed the fact that, the social, economic and political factor, which have an important bearing in desertification.

Between 1977 and 1991, much of efforts went into the issue of acquiring more precise data not only on the extent of the dryland throughout the world, but also on the status and trends of desertification. In this period
further crucial questions surrounded the use of the term as quoted by Darkoh (1999). What are the indications of desertification? What are the measurable aspects? How is desertification perceived? What is the rate of desertification? And how serious is degraded? What are the causes? What are the implications and what are the environmental, social, and economic costs of desertification? Are their evidence, mitigation and/or rehabilitation measures, which can be applied? What is technically, environmentally, institutionally, and economically feasible? Despite the efforts towards combating desertification, (UNEP) concluded that the problem of land degradation still was a serious problem.

United Notations Conference on Environment and Development (UNCED, 1992) was held in Rio de Janeiro. The conference supported a new, integrated approach to the problem emphasizing action to promote sustainable development at community level. It also called on the United Nations General Assembly to establish an Inter-governmental Negotiating Committee (INCD) to prepare by June 1994, a convention to combat desertification in these countries experiencing serious drought and/or desertification, particularly in Africa (UNCCD). The convention was adopted in Paris on 17\textsuperscript{th} June 1994, and opened for signature there on 14-15 October. It entered into force on 26 December 1996. The main objectives of (UNCCD) was to combat desertification and mitigating the effects of droughts, through effective action at all levels supported by international cooperation and partnership arrangements, in the framework of an integrated approach which is consistent with Agenda 21, with a view to contributing to the achievement of sustainable development in affected areas. The (UNCCD) involved the representatives of national governments and different Non-governmental Organizations (NGOs) from around the world and representing an arrange of science and social science disciplines.

*Global severity of desertification

The most comprehensive recent survey of the global extent and severity of desertification are those by (Dregne et. al, 1991), and (UNEP, 1992). Lanly (1995) reported the extent causes and effected of desertification and summarized its severity as follows:

Desertification threatens over one billion people worldwide. One-fifth of the entire population of the earth

Over 135 million may be in danger of being driven from their land as it becomes desert.
Two out of every three countries in the world are affected by desertification. Desertification damages almost one-third (30 percent) of the total land area of the world. About 73 percent of Africa’s drylands are moderately or severely affected by desertification.

2.1.6. General state of desertification in Sudan
2.1.6.1. Background and consequences

Sudan has experienced desertification since the forties when a soil conservation committee was established to combat land degradation. In 1958, desert and semi-desert represent 43% of the country. Drought years in the late 1960s-early 1970s and middle 1980s had affected the belt 12-18° N in Sudan. Yield dropped, for example, cereals dropped from 2.1 millions tons in 1983 to 1.47 millions tons in 1984, gum production declined from 52,000 tons in 1960 to 25,000 tons in 1973 to 15,000 tons in 1984, 2,360,000 inhabitants suffered from famine and immigration followed and the urban centers, like Khartoum, were over-populated. Immigration to outside countries constituted 21% of the total labor force, as reported by Hussein (1999).

About 64 million ha of the Sudan’s soils are affected by degradation, 81% of which are inside the dryland susceptible to desertification, thus contributing to the desertification of 33% of thus susceptible dryland reported by Ayoub (1998). Also he, mentioned that about 120 million ha of land, including 64 million of soils, are degraded to varying degrees.

2.1.6.2. Types and causes of desertification in the Sudan

*Wind erosion*

In Sudan, arid and semi-arid land (ASALs) cover an area of 1.7 million km representing about 71% of the country’s total area. Wind erosion is the major factor in the process of desertification in (ASALs) as reported by (Rizgalla, et al., 1999). Most of the northern and western states are the main areas hit by wind erosion, leaving behind large tracks of unproductive soil. Northern Kordofan and Northern Darfur are worstly hit by wind erosion, where even villages are buried under sand dune heaps as mentioned in NDDU (1999).
Erosion by wind affects 27 million ha, most of it in the hyperarid and arid zones of Kordofan and Darfur where vegetation is poor and soil particles are loose, and further accentuated by the strong winds characteristic of the region. The total area affected by wind erosion in the hyperarid zone is about 6 million ha. Just over 1 million ha is affected by wind erosion in the semi-arid zone, while the dry sub-humid and the moist sub-humid zones show no sign of wind erosion, stated by Ayoub (1998).

*Water erosion*

It occurs in many parts of the Sudan. About 18 million ha of soils are affected by water erosion. Topsoil loss through sheet erosion is the common type of water erosion, and formation of gullies is an extreme form. Water erosion occurs mostly in the semi-arid and arid zones, but 2.4 million ha along the River Nile banks in the hyperarid zone is also affected by water erosion as reported by Ayoub (1998).

*Soil compaction*

Vegetation deterioration and compaction lead to erosion and make it impossible for water to infiltrate into groundwater. Ayoub (1998) mentioned that, about 3 million ha of the Sudan’s central clay plain in the mechanized rain-fed agriculture of the Gedaref area are experiencing high physical deterioration due to the use of heavy machinery and monocropping.

Salinization/Alkalinization and waterlogging

According to (Fadul et al., 2000), both salinization and sodification have been identified as processes of land degradation, affecting the physiochemical properties of the soil, which drastically reduce plant growth and eventually lead to desertification. In the Sudan systematic soil surveys revealed only small portions of the total salt-affected areas. More extensive salt-affected soil occur in the hyper-arid and arid zones, mainly in the old alluvial sediments of the Nile, White and Blue Niles. The locations of salt-affected areas are mainly in North-western Gezira and the Managel Scheme, the higher terraces of the White Nile, the vicinity of the confluence of the Blue and white Niles and along the river Nile northwards on its higher terraces.

About 16 million ha of the ocean-like expanse of reddish yellow sandy soils of the arid and semi-arid zones in the central and southern
Kordofan and Darfur, and the dry areas are experiencing high rates of nutrient depletion as stated by Ayoub (1998).

*Overgrazing

Overgrazing is the most prevalent cause of desertification in almost all over the Sudan. This is especially so around water points and where water-table is often lowered after increased or excessive use of water. The Sudan with its rich livestock is vulnerable to desertification through overgrazing. This has led to the disappearance of some palatable species and replacement by non-palatable types in some range-lands in western Sudan. The carrying capacity of most of the range-lands in Kordofan, Darfur and Butana can hardly support the large number of livestock in the area as reported in NDDU (1999).

Akhtar (1998) reported that the regular overstocking of dry season pastures, and the uncontrolled exploitation of the vegetal resources is thus the major cause of desertification in the Butana region (Northeastern Sudan).

Ayoub (1998) mentioned that overgrazing is the most widespread cause of soil degradation particularly around settlements and watering centers, affecting about 30 m ha (47%) of the total degraded areas.

*Deforestation

In Sudan the vegetation is harvested for feed, to build homes and enclosures for animal and for fuel. Ibrahim (1984) calculated the requirements of wood per family per year as 194.5 trees and shrubs. Quarter of it is for firewood and three quarter for building homes and enclosures for animals. Ayoub (1998) concluded that the clearance of forests and wood lands cover for firewood and charcoal making and overexploitation of vegetation is the second cause of soil degradation affecting 22 M ha.

*Overcultivation

(Obeid et al., 1982) when were studying the vegetation of the central Sudan, reported that, where agricultural scheme have been established, the axe and tractor were extensively used to clear scrub and woodland in order to use the land for growing crops, for example, the Gezira irrigated scheme. Akhtar (1997) reported that the introduction
of “open access system” to the Sudan in early seventies triggered a severe and uncontrolled exploitation of the dry season or dry period grasslands. During the last four decades, supported agricultural development and the introduction of technical agricultural innovations has also induced a reduction of these crucial dry season or dry year grazing lands.

*Bush and casual fires*

The uprooting of bushes for firewood and burning of grass and forest shrubs for crop cultivation can lead to desertification. This is practiced in some areas in Central Sudan. Fires destroy the soil cover leaving it bare and hence vulnerable to erosion and desertification.

2.1.6.3. Sudan efforts to combat desertification

Aware of the threat of desertification, Sudan government has made many attempts, and adapted different techniques to harness the threat of desertification. According to Ibrahim (1984), in 1942 a commission was set up to investigate desert encroachment on the irrigated land along the Nile and on rainfed areas. In 1944 the land use law issued to regulate land tenures and land use system, in order to secure a rational use of land. In 1956, the “Rural Water Corporation” was established to supply the population of rural areas with water for human and animal use. Besides these legislations, many techniques were adopted and some pilot projects were executed in water point management, construction of fire lines, afforestation and sanddune fixation and establishment of green belts around Khartoum.

In 1976 with advice of (UNEP) and (FAO) and in response to increasing desertification, Sudan government prepared a National Plan to Combat Desertification called Desert Encroachment Control and Rehabilitation Programme (DECARP). It covers the area between Latitudes 12˚N and 18˚N from the Nile to the Western borders with Chad and along the main Nile between Longitudes 30˚ and 32˚E down to the Egyptian border (area about 650,000km²). It embodied main projects, which, include:

Establishing a national unit, for planning, development and extension.
Mapping national resources and specifying the optimum utilization.
Livestock route to alleviate pressure in natural pasture.
Desert control and combating projects.
Conservation & improvement of forest pasture livestock, soil, water resources and wildlife.

Sudan has signed all the treaties, declarations and agreements since 1960s and participated in (UNCOD, 1977). Also it has followed up meeting in 1984 where desertification was declared to the future. In 1991, the coordination unit for combating drought and desertification prepared guidelines for the National Plan for Combating Drought & Desertification. This national programme includes 12 national projects and 12 regional/international projects. The projects were distributed among the concerned government units, forestry range and pasture, animal production, wildlife, energy and cooperating units such as National Council for Research, Institute of Environmental Studies, Higher Council for Environmental and National Resources, related ministries and organizations. Sudan has ratified the (UNCCD) on 14.11.1995, and prepared the National Action Plan for combating desertification in 2002.

2.1.6.4. Geographical extent of desertification in Sudan

As stated by Salih (1996) the affected area was specified and maps produced. The affected areas located between Longitude 22° 15′- 36° 15′ E and Latitude 10° and 18° N. Six indicators of information regarding desertification (soil type; climate; vegetation cover; topography; land use systems; water resources and animal population and human activities) were compiled and analyzed in order to clarify the area ecologically affected (as shown in table 2.1.). Accordingly five classes of desertification were reached. Very severe; Severe; Moderate; Slight; Very slight, as shown in table 2.2.

The total area affected by drought and desertification is amounting to 1,259,751 km², 50.5% of Sudan’s total area. the (table 2.2.) show areas at risk to drought between Lat. 10° and 18° in Sudan.

The affected area includes: The Northern State, Nile State, Red Sea State, Kassala State, Gadaref State, Khartoum State, Gezira State, Sennar State, White Nile State, Northern Kordofan State, Western Kordofan State, Northern Darfur State and Western Darfur State.
Table 2.1. Areas of Ecological Zones of Sudan in the Zone (Lat. 10-18°N)

<table>
<thead>
<tr>
<th>Ecological Zone</th>
<th>Rainfall (mm)</th>
<th>Area (km²)</th>
<th>%zone</th>
<th>%total</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert</td>
<td>0-100</td>
<td>306.754</td>
<td>24.4</td>
<td>12.3</td>
<td>14-18° N</td>
</tr>
<tr>
<td>Semi-desert</td>
<td>100-300</td>
<td>413.830</td>
<td>32.9</td>
<td>16.6</td>
<td>13-14° N</td>
</tr>
<tr>
<td>Low rainfall savannah</td>
<td>300-800</td>
<td>512.966</td>
<td>40.7</td>
<td>20.6</td>
<td>12-13° N</td>
</tr>
<tr>
<td>Montane vegetation</td>
<td>600-800</td>
<td>0.728</td>
<td>0.1</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>High rainfall savannah</td>
<td>&gt;800</td>
<td>25.472</td>
<td>2.0</td>
<td>1.0</td>
<td>11-12° N</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.259.751</td>
<td>100</td>
<td>50.5</td>
<td></td>
</tr>
</tbody>
</table>

(Total area of Sudan 2.492 km²).
(Source: Salih, 1996)
Table 2.2. Areas at risk to drought between Lat. 10-18° N

<table>
<thead>
<tr>
<th>Desertification Classes</th>
<th>Ecological Zones</th>
<th>Rainfall (mm)</th>
<th>*Area (Km²)</th>
<th>% to Zone Area</th>
<th>% to Sudan Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert</td>
<td>Desert</td>
<td>0 - 100</td>
<td>307</td>
<td>24.4</td>
<td>12.3</td>
</tr>
<tr>
<td>V. Severe - Severe</td>
<td>Semi-Desert</td>
<td>100-300</td>
<td>414</td>
<td>32.9</td>
<td>16.6</td>
</tr>
<tr>
<td>Moderate</td>
<td>Low Rainfall Savannah</td>
<td>300-800</td>
<td>513</td>
<td>40.6</td>
<td>20.6</td>
</tr>
<tr>
<td>Slight - V. slight</td>
<td>Montane Vegetation High Rainfall Savannah</td>
<td>600-800 &gt;800</td>
<td>0.8 25</td>
<td>0.1 2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,260</td>
<td>100.0</td>
<td>49.5</td>
</tr>
</tbody>
</table>

*Area in 1000 km²
(Source: Salih, 1996)
2.2. Remote sensing and Geographic Information Systems

2.2.1. Remote sensing
Remote sensing is the collection and interpretation about an object without being in the physical contact with the object. The term remote sensing is commonly restricted to method that employ electromagnetic energy (such as light, heat and radio waves) as the means of detecting and measuring target characteristics (Sabins, 1986). Since 1960s remote sensing was in with continuous improvements in the quality of data, and increasing international cooperation and involvement.

2.2.2. Geographic Information Systems (GIS)

2.2.2.1. Definition
Definition by (ESRI, 1993) Geographic Information System is defined as "An organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyzed and display all forms of geographically referenced information," as quoted by Hamid (2000).

2.2.2.2. Fundamental and concepts of GIS
2.2.2.2.1. Data input (encoding) structure
Is defined as the conversion of spatial information from an existing format into a digital format and data structure compatible with GIS e.g. hard-copy paper maps and tables, of attributes.

2.2.2.2.2. Data management
The data management component of a GIS includes those functions needed to store and retrieve data from the database. The database can contain any type of information that is spatially distributed, ranging from socio-economic (population density) to climateological and biophysical variable (surface temperature).
2.2.2.2.3. Data manipulation and analysis

These are functions that determining the information that can be generated by GIS, for example GIS capable to make digital image processing, georeferencing, scale, projection change and remove distortion.

2.2.2.2.4. Data output

The output from GIS operations may be a hard-copy display of the spatial distribution of important thematic information on a line plotter or a list of statistics.

GIS has evolved for handling diverse data set for specific graphic area by using co-ordinates as the basis for an information system. Therefore, base on spatial nature of acquired data GIS can be used effectively to:

* Improve the quality and quantity of available remotely sensed data (aerial photographs or satellite images).

* Facilitate the creation, updating and modification of maps. i.e. employ the spatial analysis, visualization .

* Identify the potential problems and their geographical locations . GIS can find the most suitable locations according to criteria, search for patterns, association and integration, and model simulate physical & social phenomena.

* GIS is designed for assembling, integrating and analyzing spatial data in a decision-making context. Information provided by GIS can be used at operational, management and strategic planning levels by a variety of users including the scientific communities, universities and decision-makers and legislative bodies.

2.2.3. Integration of remote sensing and Geographic Information Systems:

The integrated geographic information systems defined as systems that can process images as well as raster and vector data sets in a consistent fashion stem in part from:
*Provides maximum flexibility in both display and analysis of multi-temporal and multi-spectral data.

*Stratification or subdivision into sub-region is difficult using only remote sensing data. GIS provide a mean of stratification using ancillary data.

*GIS can also be used to reclassify objects, mask objects and improve the spectral classification using simple techniques such as Green Vegetation Index with GIS decision rule.

*GIS represents the most effective mechanism for making use of data captured by remote sensing system and also enhances the effectiveness of this data capture operation through correlation of data input with already stored in a GIS) as quoted in Hamid (2000).

2.2.4. Desertification and remote sensing

Remotely sensed data can provide vital information for studying desertification and vegetation conditions. This is mainly due to its provision of high resolution area based on synoptic data collected on a regular basis, the ability to deliver composite measurements (radiation/reflectance), which integrates physical/ environmental and socio-economic data. The environment may be studied in relation to the climate, vegetation, animal biomass, human beings, soil and water.

2.2.4.1. Climate

The most important climatic features of arid regions are rainfall and wind, followed by temperature. Rainfall is nearly always unevenly distributed over the course of one or more year. When it occurs it is very heavy, of extremely short duration and extremely local, the average rainfall figures can therefore give no useful idea of actual conditions.

The wind is a major cause of erosion and hence of desertification. It increases evapotranspiration and dries the atmosphere.

2.2.4.2. Vegetation
Vegetation cover is easily detectable on satellite images, using the red and the infrared bands. It can easily be distinguished from soil, or water. The behavior of the vegetation may also be predicted the species commonly present are known. This makes it possible to cut down on field checks (Girard, 1990).

2.2.4.3. Soil
Remote sensing can monitor the conditions of the soil surface. They include: Any plant cover, the size of various course features (gravel, pebbles, stones and boulders) and their frequency and distribution, the roughness of the surface, the color, variables such as levels of lime, salt, organic matter, iron and moisture. These conditions can be interpreted by remote sensing as reported by Girard (1990).

2.2.4.4. Water
The spectral behavior of water is very different from that of soil and plants. Free water may therefore be identified without any difficulty by remote sensing in the near infra-red. It is also possible to identify cloud masses as well as air temperature and humidity, which suggests the possibility of rain prediction. It is extremely easy to monitor the changes in watercourses by comparing satellite images taken at different times, as stated in (Girard, 1990).

2.2.4.5. Livestock
The animals in semi-desert areas have a very considerable impact on the environment. Their food supply is governed by the areas where grass grows, the location of the water holes and the habits and customs of the shepherds. Other factors that must be taken into account are the number of the herds and the species of which they are composed and their size, since feeding habits and ground compaction vary with the species, as do patterns of new growth and plant species grazed. The size and number of the herds drinking at a water hole determine the paths they take. Such paths lead to compaction of the soil surface, making it impossible for many plant species to grow again. The paths most frequently used can not often be detected on SPOT images and clearly visible on aerial photographs.
CHAPTER THREE
THE STUDY AREA
NORTH-WESTERN GEZIRA

3.1. Location, Area
The study area includes the western part of the Gezira State and the north-western part of the White Nile State. It lies between longitude 32° and 33°E and Latitudes 14° and 15° N. It is bounded from the west by the White Nile and from the east by the Irrigated Gezira Agricultural Scheme (fig 1.1). The study area covers an area of 4487.8 Km². Administratively the study area followed to the White Nile and the Gezira State.
3.2. Climate

3.2.1 Rainfall

This area has been affected by the drought of the Sahelian Zone. The annual rainfall ranging from 200 mm in the north to 400 mm in the south. It affects the distribution of the vegetation. Generally the rainy season from June to September with the peak rainfall in August.

3.2.2 Winds

The prevailing winds are the trade southwestern and the trade northeastern winds. The humid trade southwestern wind move in the period from June to September and the dry trade northeastern winds move from November to October. May and October were considered as the periods of transformation in which the wind direction changes without a constant pattern. During the rainy season, often the wind direction changes suddenly due to the abrupt changes in the pressure, which occurs as a result of rainfalls (Eltayeb et al., 1995).

3.2.3 Temperature

The degree of temperate has a direct effect on the soil erosion and loosening its particles. Also it has a direct effect on the pressure which controls the wind direction and velocity. The very high temperature characterizes this part of the country in the summer especially during April – June, and this area temperature decreases to a lower degree in December & January. Also this temperature decreases during July and August, due to the action of clouds, which greatly prevents the sun radiation.

3.2.4 Relative humidity

The relative humidity directly affects the wind ability to hold the sand particles. As the relative humidity increases, the wind ability to move the sand particles decreases (Eltayeb et al., 1995). The high relative humidity in Gezira Project region is being usually during the period from July to September (rainy Season) and reaches the highest in August.

Generally the flocculation of rainfall, temperature and relative humidity percent for long period affect the vegetation cover growth and distribution. This flocculation is shown in (appendix 11).
3.3. Geomorphology and soil

The flat clay plain of central Sudan characterizes the topography of the study area. The flat topography of the Gezira was interrupted by sporadic sand deposition. Generally the soil in the study area is characterized by the light clay soils on the northern part (around Albiga, Dar alasad and Wad bilaal). And the central part consists of clay soil dominated by sand dunes especially at El getaina, Shabonat and Wad alzaki villages, while the southern part consists of heavy dark clay soil, For example at Al hashaba, Abu gebeera and Al kawa areas. (Fadul et al., 2000) concluded that, at the sand encroached site the classification of the Vertisols order has been changed to Inceptisols and Entisols orders depending on the thickness of sand deposition.

A study of the area in 2003 showed that most of the fixed dunes which were formed in the past, were reactivated and became mobile sand dunes, or Gozs as shown by Alebaid (2003). The most important Gozs are Wad Al zaki, Abu kilab, Goz Alrukba, Wadneile and Goz Shekh Muddawi. At present the following types of dunes are dominating the area: mobile sand dunes, partially fixed dunes and hummocks in addition to thin sand sheets.

3.4. Water resources

The main source of water is the White Nile and its tributaries, far from the White Nile the population depends on the rainfall for agricultural production.

All the agricultural schemes belong to White Nile Scheme Corporation (public or private sectors) depend upon the irrigation by pumps from the White Nile. The construction of Jabel Awlia dam regulates and increases the water for irrigation.

3.5. Vegetation

The character of the vegetation in Sudan depends largely on rainfall
and soil type. However, human activities (grazing, cutting, burning and cultivation) are at least as important as the physical environment in determining the changing nature of this vegetation.

Throughout the recent history of the Gezira area the cultivation cycle seems to have remained basically the same, but there have been certain changes related to the continuously increased population, the availability of drinking water for the increasing human and animal populations, and establishment of irrigated agricultural schemes.

In areas near water supplies the increasing density of population has led to lengthening of the period of cultivation and the fallow period was shortened. Where the water supply (for animal and human consumption) has seriously diminished, villages move to new sources. Where the agricultural scheme established for example the Gezira Irrigated Scheme and White Nile Schemes, the axes and tractors were extensively used to clear scrub and woodland in order to use the land for growing crops. In addition to clearing woodland and scrub for providing firewood, the area has been greatly influenced by the grazing of cattle, sheep, camels and goats.

The vegetation cover of the study area is very spare and irregularly spreaded. The species, which are present (see different plates & appendix 111)

3.5.1. Trees and shrubs:

*Acacia tortilis*
*Acacia nubica*
*Acacia nilotica*
*Acacia mellifera*
*Acacia seyal*
*Calotropis Percera*
*Capparis decidua*
*Leptadenia pyrotechnica*
*Maerua crassifolia*
*Salvadora persica*
*Ziziphus spina-christi*

3.5.2 Ground or herbaceous cover:

The study area has been greatly grazed, the annual herbs and grasses had been dominated in some places like *Panicum turgidum* found on sand & clayey soils of high humidity. Herbs and grasses had been present before three years ago when the rainfall was adequate: -
*Echinocloa colonum*

*Cassia etalica*

Plate 1. *Acacia tortilis* (seyal) and *Capparis decidua* (tundub) and *Acacia nilotica* (sunt) on part of qoz Abu kilab.

Plate 2. *Acacia tortilis* (seyal) and *Leptadenia pyrotchnica* (marikh) on qoz Abu kilab.
3.6. Land uses
There are three land use systems in the study area

3.6.1. Pastoralism
Is the traditional land use system in the drylands. The most important tribes, which are found as nomadic pastoralists in the study area, are Al hasania-Hasanat, Al mahamedia, Al hamada, and some of Al kawahla. They move with their animals in the areas near the White Nile till the central Gezira. Animals graze on trees of *Acacia tortilis*, *Capparis decidua* and *Ziziphus spina christi* and the herbs of *Dactyloctenium aegyptium*, *Ipomoea cordofana* and *Panicum turgidum*.
The livestock in this area is considered as an important source of income for the people of this area. They are goats, sheep, and camels.
Other livestock includes horses and donkeys.

3.6.2. Irrigated agriculture
*White Nile schemes*
These include all the schemes that belong to the public sector, irrigated from White Nile by pumps volumes of 8 inches and more, in which farmers grow cotton, sorghum, wheat and vegetables. These schemes were laid in Al saada (Al fatisa) and Al hashaba villages. As well as Wad Al nogumi, Al dabaseen, Mashcor, Al kawa, Al konooz and Abu hindi which in
past were belonged to private sector but at present they belong to the government.

*Private sector's farms and mataras (pump schemes)*

They includes all gardens and schemes irrigated from White Nile as well as the mataras which are irrigated from surface or ground water by pumps volumes of 3 to 6 inches for cotton, sorghum production also forage and vegetable production from mataras.

3.6.3 Traditional rainfed agriculture

In the central part of the study area, where it is far from the White Nile, the land is used mainly for traditional agriculture and grazing. The traditional agriculture is on the clay soils and around water depressions. Also in the southern part of the study area which is flat, fixed clays and not affected by sporadic deposition of sand, is considered as a suitable land for rainfed agriculture and is grown by sorghum, then after harvest is left for animal grazing.

**Problems**

The schemes of the small areas are suffering from:

1. The bad soil problems including salining and waterlogging.

2. Poor management

The present farmers were the pastarolists.

No rotation system applied.

The levels of schemes are higher than the White Nile, therefore suffering from irrigation system.

Water from (boreholes) is not sustained (problems cost of spare parts).
Plate 3. *Acacia nubica* (laot) in front and *Acacia tortilis* (seyal) on behind (Um bajbar village).

Plate 4. *Acacia nubica* (laot) in front and *Acacia tortilis* (seyal) near Naima.
CHAPTER FOUR
DESERIFICATION TREND BASED ON VEGETATION COVER ASSESSMENTS

4.1. Vegetation degradation monitoring

4.1.1. Vegetation status in 1958

Harrison and Jackson provided a national vegetation map and ecological classification system for the vegetation of the whole country in 1958 and Survey Department corrected the map.

The vegetation map of Harrison & Jackson (1958) was scanned as input into GIS database. Ilwis GIS programme was used to manage and manipulate the database. Fig 4.1 shows the vegetation of the area (Harrison & Jackson 1958). Three ecological zones are identified as follows:

1. **Acacia tortilis Maerua crassifolia desert scrub**
   This type of vegetation is found as scattered scrub interspersed with bare areas. It grows in soils of various types like the hard-surface off-flow site and desert pavement, which are bare or carry a very thin cover of annual grasses.

2. **Semi-desert grassland on clay**
   It occurs on dark cracking clays and the soil is not greatly eroded. The vegetation cover is even of mixed grasses, herbs and shrubs occur only on the sites of watercourses.

3. **Acacia mellifera – Commiphora desert scrub**
   The bushes are found as scatter on desert soils, but on the hollow between gozes it become thicker. Also *Maerua crassifolia*, *Acacia raddiana* are found. Ground cover varies, annual grasses occur like *Aristida sp.*, *Andropogon gayanus kurth*, *Indigofera oblongifolia*, *Solanum dobum*, *Reguenina obcoradata*. The most common perennials are *Panicum turgidum* and *Aristida plumosa*. *Acacia mellifera* Commiphora.
4.1.2. Vegetation status in (2002)

Visual image interpretation (that considered color/tone, texture, shape and pattern as main element of analysis) was performed to assess the potential of some of the natural resources and produce a thematic map particularly the vegetation map, (vegetation of the area depend mainly upon soil type).

The information derived from TM image dated 1996 and updated by field survey on 2002. This digital TM data was used to produce the vegetation map fig.4.2. Based upon the ecological zones of 1958(Harrison &Jackson) map, the following status of vegetation cover was mapped: -

1. Acacia tortillis Maerua crassifolia desert scrub

Dominated as very sparse scrub with large bare areas or has very thin cover of annual grasses, on the soils of on –flow sites and desert. *Maerua crassifolia* is found beside the other species like *Acacia raddiana, Leptadena pyrotechnica, Salvadora persica* which are growing on sandy drainage lines, and *Cappris decidua, Ziziphus spina-christi* and *Balanites aegyptiaca* on clay drainage lines. On the stabilized sand dunes or gozes, perennial grass like *Panicum turgidum* is dominant.

2. Semi-desert grassland on clay

The dominant vegetation mainly perennial and annual grasses and herbs like *Panicum turgidum, Dactyloctenium aegyptium, Andropogon gayanus kurth, Indigofera oblongifelia, Solanum dobum, Reguenina obcoradata, Coloaynthus valgaris, Blepharis edulis, Chrozophora brochiana, Ipomoea cordofana, Cenchrus setigerus*. The scrubs and scatter
trees found are *Acacia nubica* which is a dominant shrub, *Calotropis procera, Capparis decidua, Faidbebia albida, Leptadenia pyrotechnica*, *Prosopis chilliness*. The types of the soil vary from light clay to dark cracking clay.

3. **Acacia mellifera Commiphora desert scrub**
   This vegetation is not found.

4. **Semi-desert grassland on sand**
   The usual vegetation is a varying mixture of grasses and herbs, the woody species are almost absent but some like *Acacia raddiana, Acaica mellifera* and *Commphora spp.* are found on the hollows between the gozes. The large undulating gozes and clay with thin sand sheet characterize the area with thin grass cover.
Plate 5. Very spare vegetation of *Leptadenia pyrotechnica* (marikh) and *Panicum turgidum* (tumam) near Wad Tillib.
4.2.3. Land use/land cover pattern in the study area

Vegetation cover status in Sudan is highly correlated to landuse changes. The same landsat data were interpreted to produce a landuse/land cover map aiming at assessment of degradation that resulted from land use systems changes.

Data from the most recent landsat Thematic Mapper image 1996 was analyzed through the interpretation method and checked by field work (2002) and produced land use map of the study area consist of the main following mapping units as shown in Fig.4.4.

- Traditional rainfed agriculture.
- Non-cultivated plain (grazing areas).
- Fixed dunes.
- Partially fixed dunes.
- Cultivated White Nile schemes.
- Depressions.
- Forests of White Nile.
- Partially vegetated depressions.
- Mobile sand dunes.
Villages
4.2. Results and discussions
4.2.1. Results of vegetation map (1958)

The following results are obtained from the vegetation map (1958) after the analysis and manipulation and they are shown in table 4.1.

1. *Acacia tortillis Maerua crassifolia desert scrub*
   This vegetation covers an area of 1129Km².

2. *Semi-desert grassland on clay*
   It covers an area of 2913 Km².
3. *Acacia mellifera – Commiphora desert scrub*

The desert scrub covers an area of 445 Km².

<table>
<thead>
<tr>
<th>Mapping unit</th>
<th>Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia tortilis Maerua crassifolia desert scrub.</em></td>
<td>1129.75</td>
<td>12.5</td>
</tr>
<tr>
<td>Semi-desert grassland on clay</td>
<td>2913.25</td>
<td>32.1</td>
</tr>
<tr>
<td><em>Acacia mellifera Commiphora desert scrub</em></td>
<td>445.25</td>
<td>4.9</td>
</tr>
<tr>
<td>Gezira Scheme</td>
<td>4396.00</td>
<td>48.5</td>
</tr>
<tr>
<td>White Nile</td>
<td>178.50</td>
<td>2.00</td>
</tr>
<tr>
<td>Total</td>
<td>9063.00</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: obtained from Harrison & Jackson vegetation map of Northwestern Gezira 1958, which has been scanned and analyzed for this study.

4.2.2. Results of vegetation map (2002)

Results derived from the vegetation map produced by compilation of TM image (1996) are illustrated in table 4.2 as follows:
1. **Acacia tortilis Maerua crassifolia desert scrub**
   It covers an area of 811 Km².

2. **Semi-desert grassland on clay**
   It covers an area of 2069 Km².

3. **Acacia mellifera Commiphora desert scrub**
   The vegetation has been disappeared.

4. **Semi-desert grassland on sand**
   It covers an area of 1303 Km².

Table 4.2. Areas in km² and percentage of mapping units of vegetation map in North-western Gezira 2002

<table>
<thead>
<tr>
<th>Mapping unit</th>
<th>Area</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia tortilis Maerua crassifolia desert scrub.</td>
<td>811.25</td>
<td>9</td>
</tr>
<tr>
<td>Semi-desert grassland on clay</td>
<td>2069.75</td>
<td>22.8</td>
</tr>
<tr>
<td>Semi-desert grassland on sand.</td>
<td>1303.25</td>
<td>14.4</td>
</tr>
<tr>
<td>Gezira Scheme</td>
<td>4700.00</td>
<td>51.8</td>
</tr>
<tr>
<td>White Nile</td>
<td>178.50</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9062.75</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: obtained from vegetation map of Northwestern Gezira, which has been compiled from TM image, band 2, 3 and 4, dated 27 May 1996, for this study.
4.2.3. Comparison between past vegetation map 1958 and present vegetation map 2002

The analysis was applied to assess the vegetation changes during the forty years using ILWIS GIS software; a comparison was made between vegetation map 2002 Fig 4.2 and vegetation map 1958 Fig 4.1, the result is shown in Fig 4.3 and table 4.3. The following changes had been noticed:

1. *Acacia tortilis* Maerua crassifolia desert scrub
Gezira Scheme has used 135 km² of *Acacia tortilis* Maerua crassifolia desert scrub.
563 km² of *Acacia tortilis* Maerua crassifolia desert scrub was changed to *Semi-desert grassland on sand*.
411.5 km² of *Acacia tortilis* Maerua crassifolia desert scrub has been remained as *Acacia tortilis* Maerua crassifolia desert scrub.
19.8 km² of *Acacia tortilis* Maerua crassifolia desert scrub has been changed to *Semi-desert grassland on clay*.

2. *Semi-desert grassland on clay*
Gezira Scheme has used 175 Km² *Semi-desert grassland on clay*.
394 km² *Semi-desert grassland on clay* has changed to *Acacia tortilis* Maerua crassifolia desert scrub.
1604 km² *Semi-desert grassland on clay* has been remained as *Semi-desert grassland on clay*.
740 km² of *Semi-desert grassland on clay* has been changed to *Semi-desert grassland on sand*.

3. *Acacia mellifera* – Commphora desert scrub
445 km² of *Acacia mellifera* Commphora desert scrub has been changed to *Semi-desert grassland on clay*. 
Table 4.3. Areas in km² and percentage areas of mapping units of cross map between Harrison & Jackson’s vegetation map (1958) vegetation map (2002)

<table>
<thead>
<tr>
<th>Mapping unit</th>
<th>Area</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia tortilis Maerua crassifolia desert scrub changed to Gezira Scheme</td>
<td>135</td>
<td>1.5</td>
</tr>
<tr>
<td>Acacia tortilis Maerua crassifolia desert scrub remained as Acacia tortilis Maerua crassifolia desert scrub</td>
<td>411.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Acacia tortilis Maerua crassifolia desert scrub changed to Semi-desert grassland on clay</td>
<td>19.8</td>
<td>.22</td>
</tr>
<tr>
<td>Acacia tortilis Maerua crassifolia desert scrub changed to Semi-desert grassland on sand</td>
<td>563</td>
<td>6.2</td>
</tr>
<tr>
<td>Semi-desert grassland on clay used by Gezira Scheme</td>
<td>175</td>
<td>1.9</td>
</tr>
<tr>
<td>Semi-desert grassland on clay changed to Acacia tortilis Maerua crassifolia desert scrub</td>
<td>394</td>
<td>4.3</td>
</tr>
<tr>
<td>Semi-desert grassland on clay remained as Semi-desert grassland on clay</td>
<td>1604.25</td>
<td>17.7</td>
</tr>
<tr>
<td>Semi-desert grassland on clay changed to Semi-desert grassland on sand</td>
<td>740</td>
<td>8.2</td>
</tr>
<tr>
<td>Acacia mellifera Commiphora desert scrub changed to Semi-desert grassland on clay</td>
<td>445.25</td>
<td>4.9</td>
</tr>
<tr>
<td>Gezira Scheme remained as Gezira Scheme</td>
<td>4389.75</td>
<td>48.4</td>
</tr>
<tr>
<td>Gezira Scheme changed to Acacia tortilis Maerua crassifolia desert scrub</td>
<td>5.75</td>
<td>.06</td>
</tr>
<tr>
<td>Gezira Scheme changed to Semi-desert grassland on clay</td>
<td>.25</td>
<td>.0027</td>
</tr>
<tr>
<td>Gezira Scheme changed to Semi-desert grassland on sand</td>
<td>.25</td>
<td>.0027</td>
</tr>
<tr>
<td>White Nile changed to Semi-desert grassland on clay</td>
<td>.25</td>
<td>.0027</td>
</tr>
<tr>
<td>White Nile remained as White Nile</td>
<td>178.50</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9062.5</td>
<td></td>
</tr>
</tbody>
</table>

Source: obtained from a cross map between Harrison & Jackson vegetation map (1958) and TM vegetation map (1996) of Northwestern Gezira, which is overlaid for the
comparison between them.

4.2.4. Results of landuse/land cover pattern

Analysis and interpretation are made to produce the land use map and the following results were obtained as explained in table 4.4

Traditional rainfed agriculture is covering an area of 1780 Km².
Non-cultivated plain (grazing areas) is covering an area of 954 Km².
Fixed dunes are covering an area of 390 Km².
Partially fixed dunes are covering an area of 564 Km².
Cultivated White Nile schemes are covering an area of 154 Km².
Depressions are covering an area of 108.8 Km².
Forests of White Nile are covering an area of 64 Km².
Partially vegetated depressions are covering an area of 44.6 Km².
Mobile sand dunes are covering an area of 35 Km².
Table 4.4. Areas covered by various mapping units of landuse/land cover of the study area in km² and their percentages (1996)

<table>
<thead>
<tr>
<th>Mapping unit</th>
<th>Area</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gezira Scheme</td>
<td>4700.0</td>
<td>51.9</td>
</tr>
<tr>
<td>White Nile</td>
<td>178.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Traditional rainfed agriculture</td>
<td>1826.5</td>
<td>20.2</td>
</tr>
<tr>
<td>Non-cultivated plains (grazing areas)</td>
<td>965.8</td>
<td>10.7</td>
</tr>
<tr>
<td>Partially fixed dunes</td>
<td>552.8</td>
<td>6.1</td>
</tr>
<tr>
<td>Fixed dunes</td>
<td>397.9</td>
<td>4.4</td>
</tr>
<tr>
<td>Cultivated white Nile schemes</td>
<td>153.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Depressions</td>
<td>108.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Forest of White Nile</td>
<td>64.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Partially vegetated depressions</td>
<td>44.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Mobile sand dunes</td>
<td>35.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Densely vegetated depressions</td>
<td>13.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Solid rocks</td>
<td>11.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Villages</td>
<td>5.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Alrajja scheme</td>
<td>2.3</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9062.5</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: landuse/land cover map of Northwestern Gezira which has been compiled from TM image, band 2,3, and 4, dated 27 May 1996 for this study.
Plate 7. Different species of Acacia mellifera (kitir), Acacia nilotia (sunt), Acacia tortills (seyal) and Indigofera oblongifelia (dahasir) near Um bajbar.

Plate 8. Different species of Acacia nilotia (sunt), Acacia tortills (seyal), Acacia nubica (laot) and Capparis decidua(tundub) on depression near Almagair.
4.3. Discussions of results
4.3.1. Monitoring vegetation changes (1958-2002)

The area of *Acacia tortilis Maerua crassifolia desert scrub* has been changed to *Semi-desert grassland on clay* at 22%, and to *Semi-desert grassland on sand* at 6.2%, from the field check, the vegetation is very spare with large bare areas and this is contributing to desertification.

Appearance of *Semi-desert grassland on sand* at 14.4% as in table 4.2. and occurred on the soil of on–flow surface (mobile & stabilized dunes) as shown on Fig.4.2 is due to the wind erosion which affected area and this is accelerating the process of desertification.

*Semi-desert grassland on clay* had been remained as *Semi-desert grassland on clay* at 17.7% (table 4.3), this because of the soil type of the study area to some extent was not affected by wind erosion.

*Acacia mellifera Commiphora desert scrub*, which has been changed to *Semi-desert grassland on clay* at 4.9%. The remarkable thing is the spreading of *Acacia nubica* on the belt of semi-desert grassland on clay, and this is an indicator of overgrazing which is increasing the process of desertification.

*Semi-desert grassland on clay* has changed to *Acacia tortilis Maerua crassifolia desert scrub* at 4.3%, it consider as an effective change, this
may be due to clay type of the soil as well as the rainfall for this period helps in the revegetation of that part (see plate 8).

4.3.2. Desertification trend based on over-exploitation of the natural resources (land use changes)

*Overcultivation

As mentioned earlier, in the central part of the study area, where it is far from the Nile, the land is used mainly for traditional agriculture and grazing. So the traditional or rainfed agriculture is on the clay soil and around water depressions. The farmer in rainfed agricultural areas, practices this sort of cultivation, in which a small piece of land is cleared by felling and burning all or most of trees and shrubs. Then grown by sorghum for 5-15 years, then after the yield decreases, the farmer moves to new areas and repeat the cycle. The soil becomes more susceptible to erosion because of low organic matter and the fact that the soil is left without vegetation cover for longer period each year. The exposed topsoil is crusted by combined impact of rain and sun, blown away by wind, or washed away by water. As in table 4.4 about 20.2 % of the total area has been used by traditional rainfed agriculture, accordingly this subjects the area to the desertification. At present the same area is very much characterized by the absence of trees and shrubs. The people from these area argue that their land has become desert like. As shown in fig 4.4 the over-exploitation of the fragile land in this area has led to desertification. Beside that most of the White Nile agricultural schemes whether they belonged to public or private sector, the arable land were affected by sand dune encroachment and resulted in the reduction of the agricultural areas and crop yields. This is leading to the increases of desertification process.

*Overgrazing

As mentioned in Chapter Three, the grazing animals of this area, are goats, sheep, cattle and camel, they cover large distances as they move from the White Nile to the central Gezira, with their owners in typical nomadic lifestyle. But after the construction of Jabel Awlia dam, establishment of White Nile Schemes and expansion of Agricultural Gezira Project and uncontrolled exploitation of the rangeland all these had led to decreases in the rangeland resources. Now only 10.7 % of the total area are rangelands as shown in table 4.4. Usually after the harvest period, nomadic pastoralists move towards Gezira
Project and White Nile schemes to graze crop residues (Sorghum & groundnut). This is resulted in the damaging of cotton crop that is considered as the basic source of the national economy of the Sudan. During the summer, which is with scarcity of water, the nomad moves towards the White Nile bank.

During the flood season or reduced rainfall, there is no available natural range resource, so the nomads use the stored dried pastures. Therefore the continued overexploitation has led to the deterioration and exhaustion of the rangeland in the following effects:

Overgrazing and deterioration of the vegetation cover which led to desertification and sand dune encroachment. Now most of the rangeland of the study area is covered by partially fixed dunes are about 552.8 km², fixed dunes are about 397.9km² and mobile sand dunes are 35.6km² as shown in Fig 4.4 and table 4.4.

Palatable species have decreased and been replaced by unpalatable species like *Dactyloctenium aegptium, Cenchrus ciliaris, Aristida spp, IPomoea cardofanum, Acacia tortilis* and *Leptadenia pyrotechnica* are usually replaced by *Cenchrus setigerus*.

Some trees are replaced by shrubs which are strongly deformed by browsing animals, such as *Maerua crassifolia, Ziziphus Spina christi* are dominated by *Calotropis procera, Acacia nubica*. These last two are indicators of heavy grazing pressure. (As shown in Fig.4.2)

Overgrazing in some parts of the study area has led to complete changes in the vegetation leaving only scattered trees and shrubs of low palatability. In other part complete destruction of all vegetation resulted in the desertification.

*Fuelwood cutting:*

Trees and shrubs are cut in this area and used as fuelwood for cooking, beside that some factories (Bakers and mud bricks makers) use the woody fuel. In some villages fuel gathers (especially women) utilize any woody plant and so they are even more
destructive than grazers. But in other villages people are aware of the effects of cutting trees and shrubs so they are using gas. Others were not cutting the tree and shrubs but they were using the fallen trees and dried grasses.

We noticed the over-exploitation of woody vegetation for the fuel wood in the area under consideration is generally one of the leading causes of soil erosion and increasing the desertification process.

*Forest Degradation:
The situation with riverain forest degradation is also very dramatic. We knew from literature and group discussions there were big areas near the White Nile which had been considered as forest. But nowadays are considered spare rangeland or even bare land. That means the size of the forest area reduced during the last 100 years. Degradation of forest is a problem in the study area. As known in the map of land use Fig.4.4 only 0.7 % of the total area is covered nowadays with forest near the White Nile, which is including the species like *Salvadora Persica, Acacia mellifera*
CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The adverse climatic conditions have led the population in the study area to develop some sorts of lifestyle for survivals based on certain pattern of social organization, usually involving the seeking of water places and sources of food for themselves and their herds leading to over-exploitation of the resources.

Fluctuations in the rainfall, temperature and occurrence of periodic droughts in the study area had great negative effects on vegetation cover, which stimulated the process of desertification.

Wind erosion plays an important role in vegetation transition from *Acacia tortilis Maerua* *crassifolia desert scrub in Harrison & Jackson map* to *Semi-desert grassland on sand*.

Rainfed agriculture in the area under consideration has been progressively extended at the expense of the best grazing lands, and the natural plant cover, which had been destroyed.

In irrigated schemes of White Nile, the areas grown by wheat, sorghum and vegetables have decreased due to the sand deposition on water canal beside the other problems, leading to desertification.

Overgrazing in this area has led to the complete changes in vegetation leaving only areas of shrubs of low palatability and in other areas complete devastation of all vegetation resulting in desertification.
It has been recognized that, over exploitation of woody resources, especially for meeting of energy needs has been an important factor in desertification in the study area.

The data acquired from satellite Thematic Mapper (TM) provide an excellent source for mapping and analyzing the desertification process. Because of their potential, GIS and remote sensing are major tools for managing natural resources. The potential of GIS for storing useful information and its capacity to cross- link them was fully utilized to highlight the change detection and vegetation degradation areas. Various factors (extension of land under cultivation, overgrazing and pulling up woody plant) have resulted in weakening of the natural resources, lessening of their capacity for regeneration and decreased in their production potential.

5.2. Recommendations
The study area of most fragile zone, i.e. Semi arid, the over- exploitation of the natural resources has been made the land more prone to desertification and led to almost irreversible forms of degradation, despite of that, the following recommendations are raised for rehabilitation of the vegetation cover:

Using the optimum system of range management by letting the livestock to graze moderately and allowing the vegetation to reach the flowering stage, which eventually help the plant to shed seeds and to reappear in the following rainy season.

Distributing the improved range seed like perennial grasses (*Cenchrus* spp. and *Panicum Turgidum*) in the protected depressions and wadis.
Establishing of enclosures for protecting the rangeland. Establishing green belts around sand dune areas by using some of the desert enduring plant such as Eucalyptus spp, *Panicum turgidum* and *Prosopis chilensis*.

Planting of various type desert tolerant trees and shrubs in cities and villages around the study area. Detailed studies have to be made on the quantitative side of the plant species in the study area in order to monitor and control the desertification effectively.

Investigation of the demographic and socio-economic conditions, so as to achieve a better understanding of the relation between the natural potential and its present day exploitation.

**For degradation assessment, mapping and monitoring, the following are suggested:**

Use of remote sensing and GIS because as important tools in land degradation studies, as they have been efficiently used for assessing landuse and desertification to be used in the other areas prone to desertification in the Sudan.

Use of the low-resolution sensors like Advance Very High-Resolution Radiometer (AVHRR) type data from the National Oceanic and Atmospheric Administration (NOAA) satellite. Because it posses a ground resolution of about 1 to 4 Km, which makes it most appropriate tool for studying and monitoring the vegetation degradation over large areas.

Use of (AVHRR) data over a period of time in order to monitor the risk, current status and the rate at which the degradation occurs.
Use vegetation indices: Because these indices are frequently used to study vegetation. They are based on the reflectance of objects in the red and near infrared, and try to isolate the vegetation from other factors, which are integrated into recorded reflectance. One of these indices is currently used called NDVI (Normalized Difference Vegetation Index) to give satisfactory results in order to map the vegetation cover over large expanses. The study of seasonal variations or annual variations in this index reflects the changes in the photosynthetic activity of the vegetation. Periods of drought are therefore marked by a substantial fall in the NDVI.
REFERENCES


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UNSO, 1979. Assessment of the problem of desertification and review of ongoing and proposed activities to implement the plan of action to combat desertification in the Democratic Republic of the Sudan. New York.

Article 1.


## APPENDIX I

### Some Definitions of Remote Sensing & GIS

<table>
<thead>
<tr>
<th>Words</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band</td>
<td>Wavelength interval in the electromagnetic spectrum. For example, in Landsat image the band designated specific wavelength intervals at which images are acquired.</td>
</tr>
<tr>
<td>GIS</td>
<td>GIS makes it possible to link, or integrate, information that is difficult to associate through any other means. Thus, a GIS can use combinations of mapped variables to build and analyze new variables.</td>
</tr>
<tr>
<td>Data Integration</td>
<td>Computer manipulation of digital number values of an image.</td>
</tr>
<tr>
<td>Digital image processing</td>
<td>Process of converting an analog display into a digital display.</td>
</tr>
<tr>
<td>Digitization</td>
<td>It refers to all energy that moves with the velocity of light in a harmonic waves pattern. A harmonic pattern consists of waves that occur at equal intervals in time.</td>
</tr>
<tr>
<td>Electromagnetic energy</td>
<td>Process of altering the appearance of an image so that the interpretation can extract more information.</td>
</tr>
<tr>
<td>Enhancement</td>
<td>Width of the strip of terrain that is imaged by scanner system.</td>
</tr>
<tr>
<td></td>
<td>Is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information, i.e. Data identified according to their locations. Practitioners also regard the total GIS as including operating personal and the data go into system.</td>
</tr>
<tr>
<td>Ground swath</td>
<td>ANOAA satellite that acquires visible and thermal IR images for meteorological purposes.</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Geographic Information System</td>
<td>The process in which a person extracts information from an image.</td>
</tr>
<tr>
<td>Geostationary Operational Environmental Satellites</td>
<td>Infrared region of the electromagnetic spectrum that includes wavelengths from 0.7um to 1mm.</td>
</tr>
<tr>
<td>Interpretation</td>
<td>A series of unmanned earth-orbiting NASA satellite that acquires multispectral image in various visible and IR.</td>
</tr>
<tr>
<td>IR</td>
<td>A system of Landsat that acquires images at four wavelength band in the visible and reflected IR regions.</td>
</tr>
<tr>
<td>Landsat</td>
<td>Using maps of vegetation, wetlands, slope, streams, land use and soils, the GIS might produce a new map layers or overlay that ranks the wetlands according to their relative sensitivity to damage from nearby factories or homes.</td>
</tr>
<tr>
<td>Multispectral Scanner</td>
<td>System for locating Landsat MSS and TM images</td>
</tr>
<tr>
<td><strong>Overlay</strong></td>
<td>Ratio of the radiant energy reflected by a body to the energy incident on it. Spectral reflectance in the reflectance measured within a specific wavelength interval.</td>
</tr>
<tr>
<td><strong>Path and row index</strong></td>
<td>Collection and interpretation of information about object without being in physical contact with the object.</td>
</tr>
<tr>
<td><strong>Reflectance</strong></td>
<td>Ability to separate closely spaced object on an image or photograph. Resolution is commonly expressed as the most closely spaced line-pairs per unit distance that can be distinguished. Also called spatial resolution.</td>
</tr>
<tr>
<td><strong>Remote Sensing</strong></td>
<td>A system in which images are formed on the photosensitive surface of a vacuum tube, the image is scanned with an electron beam and transmitted or recorded. Landsat 3 used a system of RBVs to acquire images.</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>An object in orbit around a celestial body.</td>
</tr>
<tr>
<td><strong>Return Beam Vidicon(RBV)</strong></td>
<td>Reflectance of electromagnetic energy at specified wavelength intervals.</td>
</tr>
<tr>
<td></td>
<td>System Probatoire d’Observation d Terre.Unmmaned French remote sensing satellite orbiting in the late 1980.</td>
</tr>
</tbody>
</table>
| | Earth satellite orbit plane nearly polar and the altitude is such
<table>
<thead>
<tr>
<th>Satellite</th>
<th>that the satellite passes over all places on earth having the same latitude twice daily at the same local sun time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral reflectance</td>
<td>A cross track scanner system developed on landsat that records seven bands of data from the visible through the thermal IR region</td>
</tr>
<tr>
<td>SPOT</td>
<td>IR region from 3 to 14 um that is employed in remote sensing. This spectral region spans the radiant power peak of the earth.</td>
</tr>
<tr>
<td>Sun-synchronous</td>
<td>Distance between successive wave creates or other equivalent points in a harmonic wave.</td>
</tr>
<tr>
<td>Thematic Mapper(TM)</td>
<td></td>
</tr>
<tr>
<td>Thermal IR</td>
<td></td>
</tr>
<tr>
<td>Wavelength</td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX II
## Ed dueim average Rain, grand average TEMP. and Relative Humidity%

for the period (1970-2001)

<table>
<thead>
<tr>
<th>Year</th>
<th>average Rain</th>
<th>Max.aver TEMP</th>
<th>Min.aver TEMP</th>
<th>grand aver. TEMP.</th>
<th>Relative Humidity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
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<td>36.27</td>
<td>22.24</td>
<td>29.25</td>
<td>34.33</td>
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<td>21.1</td>
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<td>33.25</td>
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<tr>
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<td>18.08</td>
<td>10.12</td>
<td>14.1</td>
<td>31.58</td>
</tr>
<tr>
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<td>9.78</td>
<td>37.24</td>
<td>22.09</td>
<td>29.67</td>
<td>36.25</td>
</tr>
<tr>
<td>1974</td>
<td>8.43</td>
<td>33.08</td>
<td>19.83</td>
<td>26.45</td>
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<tr>
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<td>33.58</td>
<td>20.71</td>
<td>27.14</td>
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</tr>
<tr>
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<td>36.51</td>
<td>22.78</td>
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<td>34.17</td>
</tr>
<tr>
<td>1977</td>
<td>11.43</td>
<td>35.42</td>
<td>21.81</td>
<td>28.61</td>
<td>32.42</td>
</tr>
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<td>32.53</td>
<td>22.28</td>
<td>27.4</td>
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<td>23.13</td>
<td>28.12</td>
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<td>36.52</td>
<td>22.73</td>
<td>29.63</td>
<td>36.08</td>
</tr>
<tr>
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<td>19.61</td>
<td>36.37</td>
<td>22.08</td>
<td>29.23</td>
<td>36.17</td>
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<td>36.38</td>
<td>22.01</td>
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<td>35.08</td>
</tr>
<tr>
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<td>36.23</td>
<td>21.93</td>
<td>29.08</td>
<td>35.25</td>
</tr>
<tr>
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<td>37.58</td>
<td>22.81</td>
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<td>29.61</td>
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</tr>
<tr>
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<td>36.78</td>
<td>21.93</td>
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<td>37.23</td>
<td>22.53</td>
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<td>34.33</td>
</tr>
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<td>36.68</td>
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</tr>
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<td>22.5</td>
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<td>20.74</td>
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<tr>
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<td>36.91</td>
<td>20.85</td>
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</tr>
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<td>30.11</td>
<td>36.34</td>
<td>20.52</td>
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</tr>
<tr>
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<td>27.56</td>
<td>36.77</td>
<td>22.18</td>
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</tr>
<tr>
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<td>18.72</td>
<td>36.89</td>
<td>21.97</td>
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<tr>
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<td>36.28</td>
<td>22.25</td>
<td>29.26</td>
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</tr>
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<td>36.56</td>
<td>22.46</td>
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<tr>
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<td>36.72</td>
<td>22.67</td>
<td>29.69</td>
<td>39.58</td>
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<tr>
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<td>36.63</td>
<td>22.06</td>
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<td>36.25</td>
</tr>
<tr>
<td>2001</td>
<td>22.52</td>
<td>36.75</td>
<td>20.76</td>
<td>28.75</td>
<td>38.08</td>
</tr>
</tbody>
</table>

APPENDIX 111

The species of the woody and herbaceous plant in the study area

1. The woody trees and shrubs

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Local Name</th>
<th>Life Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia tortilis</td>
<td>Seyal</td>
<td>Tree</td>
</tr>
<tr>
<td>Acacia nubica</td>
<td>Laot</td>
<td>Shrub</td>
</tr>
<tr>
<td>Acacia nilotica</td>
<td>Sunt</td>
<td>Tree</td>
</tr>
<tr>
<td>Acacia mellifera</td>
<td>Kitir</td>
<td>Tree</td>
</tr>
<tr>
<td>Acacia seyal</td>
<td>Taleh</td>
<td>Tree</td>
</tr>
<tr>
<td>Acacia senegal</td>
<td>Hashab</td>
<td>Tree</td>
</tr>
<tr>
<td>Balanite aegyptica</td>
<td>Heiglig</td>
<td>Tree(Evergreen)</td>
</tr>
<tr>
<td>Calotropis procera</td>
<td>Usher</td>
<td>Tree/Shrub(Evergreen)</td>
</tr>
<tr>
<td>Commiphora spp.</td>
<td>Gafal</td>
<td>Small trees or shrub</td>
</tr>
<tr>
<td>Capparis decidua</td>
<td>Tundub</td>
<td>Shrub(Evergreen)</td>
</tr>
<tr>
<td>Faidbebia albida</td>
<td>Haraz</td>
<td>Tree/Shrub</td>
</tr>
<tr>
<td>Leptadenia pyrotechnica</td>
<td>Marikh</td>
<td>Shrub(Evergreen)</td>
</tr>
<tr>
<td>Maerua crassifolia</td>
<td>Sarieh</td>
<td>Shrub(Evergreen)</td>
</tr>
<tr>
<td>Prosopis chilliness</td>
<td>Mosquate</td>
<td>Tree/Shrub</td>
</tr>
<tr>
<td>Salvadora persica</td>
<td>Arak</td>
<td>Tree</td>
</tr>
</tbody>
</table>

2. The grasses and herbs

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Local Name</th>
<th>Life Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aristida mutabilis</td>
<td>Gau</td>
<td>Annual (Grass)</td>
</tr>
<tr>
<td>Aristida pallida</td>
<td>Umm semima</td>
<td>Perennial (Grass)</td>
</tr>
<tr>
<td>Blepharis edulis</td>
<td>Seha</td>
<td>Grass</td>
</tr>
<tr>
<td>Cymbopogon proximus</td>
<td>Mahrieb</td>
<td>Grass</td>
</tr>
<tr>
<td>Cassia italica</td>
<td>Senna sena</td>
<td></td>
</tr>
<tr>
<td>Citrullus colocynthis</td>
<td>Handal</td>
<td>Annual(Runner)</td>
</tr>
<tr>
<td>Andropogon gayanus kuth</td>
<td>Abu rukhyas</td>
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</tr>
<tr>
<td>Chrozophora</td>
<td>Aragasi</td>
<td>Perennial(Evergreen)</td>
</tr>
<tr>
<td>Scientific Name</td>
<td>Common Name</td>
<td>Type</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td><em>Cenchrus ciliaris</em></td>
<td>Haskanit naam</td>
<td>Annual (Grass)</td>
</tr>
<tr>
<td><em>Cenchrus biflorus</em></td>
<td>Haskaneet khishin</td>
<td>Annual (Grass)</td>
</tr>
<tr>
<td><em>Dactyloctenium aegyptium</em></td>
<td>Abu assabi</td>
<td></td>
</tr>
<tr>
<td><em>Echinochloa colonum</em></td>
<td>Dafra</td>
<td></td>
</tr>
<tr>
<td><em>Indigofera oblongifolia</em></td>
<td>Dahasir</td>
<td>Perennial</td>
</tr>
<tr>
<td><em>Ipomoea cordofana</em></td>
<td>Hantoot</td>
<td>Annual</td>
</tr>
<tr>
<td><em>Ipomoea sp.</em></td>
<td>Taber</td>
<td>Annual</td>
</tr>
<tr>
<td><em>Panicum trugidum</em></td>
<td>Tumam</td>
<td>Perennial (Grass)</td>
</tr>
<tr>
<td><em>Reguenina obcorodata</em></td>
<td>Adan Al far</td>
<td>Perennial</td>
</tr>
<tr>
<td><em>Solanum dobium</em></td>
<td>Jubian</td>
<td></td>
</tr>
</tbody>
</table>