A STUDY OF DESERTIFICATION AND LAND DEGRADATION IN NORTHWEST OF LIBYA USING REMOTE SENSING

By

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LIST OF ABBREVIATIONS

Abbreviations	Description
ACSAD	The Arab Centre for the Studies of Arid Zones and Dry Lands
Ave	Average
CQI	Climatic Quality Index
DN	Digital Number
DRI	desertification risk index
ESAI	Environmental Sensitivity Areas Index
EMR	Electromagnetic Radiation
ESAI	Environmental Sensitive Area Index
FAO	Food Agricultural Organization
GIA	General Information Authority
GWA	General Water Authority
GCOS	Global Climate Observing System
GEO	Group of Earth Observation
GIS	Geographic Information System
GPS	The global positioning system
GCLF	Global Land Cover Facility
IACD	The International Agreement on Combating Desertification
IFAD	International Fund for Agricultural Development
ILWIS	Integrated Land and Water Management System software
LSSs	Land-surface Scheme

iLSSs	Isotopic LSSs
IMF	International Monetary Fund
IRC	Industrial Research Centre
ITC	The International Institute for Aerospace Survey and Earth Sciences
IYDD	The International Year of Deserts and Desertification
LGIA	Libya General Information Authority
LGPC	Libya General Planning Council
LNMC, CD	Libyan National Meteorological Center, Climatological Department
MEA	Millennium Ecosystem Assessment
NDVI	Normalized Difference Vegetation Index
NIR	Near-infrared Band
RGB	The primary color-gun (red, green, and blue),
RS	Remote Sensing
SPSS	Statistical Package for the Social Sciences
SWI	stable water isotopes
SWIR	Mid-infrared
SQI	Soil Quality Index
TIR	Thermal Infrared
TM	Thematic Mapped
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCOD	United Nations Conference on Desertification
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations plan of action to combat desertification

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNGA	United Nations the General Assembly
USGS	United States Geological Survey
UTM	The Universal Transverse Mercator projection
VQI	Vegetation Quality Index

Stations of the Study Area

TRI	Tripoli
T-AIR	Tripoli Airport
ZAH	Az Zahra
ZAW	Az Zawia
SUR	Surman
SAB	Sabratha
ZUW	Zuwarah
AZIZ	Al Aziziyah

LIST OF SYMBOLS

symbols	Description
r	The Percentage of Population Growth Rate
$R^{'}$	The Average Annual Population Growth
$P^{'}$	The Average Total of Population in two Successive Censuses
P_1	The Total Number of People in the Previous Census
P_2	The Total Number of People in the Second Census
t	The Time or Years Number
$\bar{X}_d$	The Arithmetic Density
T_p	The Total Population
T_a	The Total Area
$\bar{X}$	Arithmetic Mean
R	Temperature Range
R_c	Rain Concentration
$\min(x_i)$	The Smallest Value
$\max(x_i)$	The Biggest Value
μm	A Micrometer or Micron, it is 1 millionth of a meter
Q_2	The Actual Amount of Rainfall
M	The General Annual Average of Rain Quantities
T_2	The Mean of the Upper Degree of Temperature
T_1	The Mean of the Lowest Degree of Temperature

T_s	The Total Seasonal Rain
F	F Test
V_b	The Variance Between the Groups
V_w	The Variance Within the Groups
K	The Number of Stations
CV	Coefficient of Variation
S	Standard Deviation
C	Centigrade
´	Minutes

SATU KAJIAN DESERTIFIKASI DAN DEGARADASI TANAH DI UTARA BARAT LIBYA MENGGUNAKAN PENDERIAAN JAUH

ABSTRAK

Kajian ini mengenal pasti masalah desertifikasi dan tahap keterukannya di dalam kawasan kajian. Penyelidikan ini dijalankan di Dataran Jafara yang terletak di Utara-Barat Libya kerana ia merupakan salah satu kawasan penting di dalam negara ini yang mempunyai kepadatan populasi yang tinggi. Lebih daripada 50% jumlah penduduk di dalam negara yang tinggal di dataran ini. Dataran ini meliputi lebih daripada 60% jumlah ladang pertanian di Libya. Ia juga menghasilkan lebih daripada separuh keperluan pertanian negara. Kajian ini menggunakan Penderiaan Jauh sebagai sumber utama dalam pengumpulan data dan analisis. Imej satelit kawasan kajian dianggap sebagai data utama yang digunakan dalam kajian ini. Imej Landast5 TM dipilih kerana resolusi ruang yang terdapat dalam imej satelit dan saiz kawasan kajian. Dua data Landsat tanpa-awan dengan tarikh yang berbeza (1989 dan 2005) bagi Laluan 189 dan Baris 037 yang disediakan oleh Pusat Penderiaan Jauh dan Sains Angkasa Libya, meliputi kawasan kajian. Data satelit ini digunakan untuk mendapatkan pemetaan tanah, vegetasi dan bukit pasir yang melitupi kawasan kajian. Tambahan pula, data dianalisis secara statistik menggunakan SPSS. Ia menunjukkan bahawa faktor semula jadi dan manusia saling bertindak menyebabkan pencepatan proses desertifikasi di rantau ini. Pertumbuhan penduduk dan tekanan populasi ke atas sumber alam yang terdapat di rantau ini seperti peluasan agrikultur di tanah marginal, pertambahan jumlah haiwan, eksploitasi air bawah tanah yang berlebihan dan perbandaran mempercepatkan fenomena desertifikasi. Analisis daripada imej satelit menunjukkan bahawa kawasan pertanian berkurangan disebabkan penyalahgunaan sumber pertanian dan air bawah tanah. Ini memburukkan lagi proses

degaradasi tanah di rantau ini dan meningkatkan sensitiviti desertifikasi. Kajian menyarankan supaya kerjasama di antara negeri, organisasi tempatan dan bukan kerajaan, kebangsaan dan sub-rantau, rantau dan agensi antarabangsa untuk memantau penilaian dan kawalan desertifikasi dengan menggunakan strategi daripada Konvensyen Bangsa-bangsa Bersatu bagi memerangi desertifikasi. Rangka kerja yang terurus serta penggunaan teknik penderiaan jauh dan sistem maklumat geografik diperlukan bagi membina pangkalan data yang meningkatkan kebolehan menjejaki dan menaksir desertifikasi. Selain itu, ukuran harus dilaksanakan bagi menggalakkan penyelidikan saintifik dalam bidang perlindungan alam sekitar dan memerangi degeradasi tanah dan desertifikasi. Ukuran mungkin membantu dan membolehkan pembuat keputusan bagi merangka dan memerangi desertifikasi.

A STUDY OF DESERTIFICATION AND LAND DEGRADATION IN NORTHWEST OF LIBYA USING REMOTE SENSING

ABSTRACT

This study identifies the desertification problems and their degree of severity in the study area. The research is conducted in the Jafara Plain which is located in the North-West of Libya because it is one of the most important areas in the country where there is high population density. More than 50% of the total population of the country resides in this plain. The plain constitutes more than 60% of the total irrigated agricultural land in Libya. It also produces more than half of the country's agricultural needs. The study employs the use of Remote Sensing as the major source of data gathering and analysis. Satellite images of the study area are considered as the main data used in this study. Considering spatial resolution of the available satellite images and the size of the study area, Landsat5 TM images are selected for this study. Two cloud-free Landsat data with different acquired dates (1989 and 2005) for Path 189 and Row 037 provided by the Libyan Center for Remote Sensing and Space Science, covering the investigated area are used in this research. These satellite data are used in order to obtain the advantages of their ability in mapping soils, vegetation and sand dunes, which covered some places in the study area. Moreover, the data are analyzed statistically by using SPSS. It is revealed that natural and human factors are interacted in causing the acceleration of the desertification process in the region. Population growth and population pressure on the available natural resources in the region, such as, agricultural expansion into the marginal lands, increased livestock numbers, over-exploitation of underground water and the extension of urbanization have led to the acceleration of the desertification

phenomenon. It was found from the analysis of satellite images that the agricultural land decreased because of the misuse of agricultural resources and underground water. These have exacerbated the process of land degradation in the region and increased sensitivity to desertification. The study recommends that there should be collaboration between state, local and non-governmental organizations, national and sub-regional, regional and international agencies to monitor evaluate and control desertification by adopting strategies of United Nations Convention to combat desertification. A well-managed framework, as well as application of remote sensing techniques and geographic information systems to create databases that enhance the capabilities for tracking and assessing desertification, are needed. Besides, measures should be implemented to encourage scientific research in the field of environmental protection and combating land degradation and desertification. The measures might assist and enable decision-makers to plan and combat desertification.

CHAPTER 1

INTRODUCTION

1.1   Background of the study

Desertification has been defining as 'land degradation in arid, semi-arid and dry sub-humid areas. Desertification is a result of several factors, which include climatic fluctuations and human activities (UNCCD, 2007). Desertification, drought and climate change often represent slow onset hazards. According to Millennium Ecosystem Assessment (MEA) of (2005), desertification is caused by a combination factors that change over time and vary by location. It is a worldwide phenomenon affecting about one-fifth of the world population. Desertification has also affected about 70% of all dry lands representing about 3.6 billion ha and one-quarter of the total land area of the world. Every year, an additional 200,000 km^2 of productive land are lost to desertification to the extent of yielding nothing (Abahussain et al., 2002; El-Tantawi, 2005; Saad and Shariff, 2011). However, some authors have pointed out that desertification has not been considered a key issue by the developed countries, and a reason for this can be that the United Nations convention to combat desertification emerged as an 'African' convention (Seely et al., 2008). The United Nations reports indicate that about 35 million km^2 of land all over the world are subject to desertification effects (El-Hassan, 2004). The problem of desertification is not only confined to arid or semi-arid regions in the world, it also extends to the adjacent semi-humid and tropical regions.

Many conferences have been held to investigate desertification process. Examples of such conferences include but not limited to: United Nations Conference on

Desertification (UNCOD) Nairobi 1977, The Ad-Hoc Consultative Meeting on Assessment of Global Desertification: status and methodologies, February 1990, UNEP- Nairobi and international conferences held in October 1994 and May 1997 in Tucson, Arizona, USA, in support of United Nation Convention to Combat Desertification (UNCCD). These conferences raised the world's awareness on the effects and causes of desertification and provided programs of action for sustainable development and combating desertification (El-Tantawi, 2005).

Desertification is a gradual process during which the productivity of land is reduced. These processes have affected about 46% of whole Africa (Reich et al., 2004). The causes of dry land degradation have been widely discussed in the literature but still remain controversial (Thomas, 1997; Bregas, 1998; Lambin et al., 2001; Reynolds and Stafford Smith, 2002; Geist and Lambin, 2004). However, most authors (e.g. Turner et al., 1995; Puigdefábregas, 1995; Geist and Lambin, 2004) agreed that there is more than one factor that causes desertification or land degradation. Both biophysical and socio-economic factors need to be jointly considered because they interact and reinforce each other to induce transition trigger events (Turner et al., 1995; Bregas, 1998; Lambin et al., 2001). These authors have concluded that various human-environment conditions react to and pre-shape the impacts of drivers differently, leading to specific pathways of land-use change and desertification.

The International Year of Deserts and Desertification (IYDD) was adopted as a way of ''raising public awareness about desertification'' and ''helping to protect dry land biodiversity, the knowledge and traditions of the people whose everyday lives are affected by desertification'' (United Nations the General Assembly (UNGA), 2004).

It is clear that although receiving attention for a longer period of time, the conceptual and quantitative understanding of desertification does not appear more advanced than that of climate change. This may at least partially be due to the complex biophysical and socio-economic nature of both phenomena, as well as the difficulties in communicating the understanding of their causes, effects, and initiating suitable reversal or mitigation measures. Moreover, desertification has attracted much less sustained attention from the international community, and this is having a negative impact on the rate of advances in this field (Seely et al., 2008).

Mapping desertification prone areas is needed for developing a more thorough scientific understanding of the dynamic processes and driving forces. It also forms an important requirement for the drafting and implementation of development plans and policy decisions about the sustainable use of Mediterranean land resources (Hill et al., 1995; Lacaze et al., 1996). Hence, mapping and monitoring constitute important activities necessary for the implementation of development plans and policy decisions concerning the methods of combating desertification. This would assist in the prevention of valuable losses to ecosystems, their productivity, and the productivity of those dependent on them (Sahsuvaroglu, 2001). Desertification and its spatio-temporal evolution information are very important to desertification and also to effectively implement macro-management, which could be helpful to promote environmental resources sustainable development (Jianjun et al., 2004).

Fragility of dry land ecosystems is an inherent attribute that relates to a number of ecological features which include: limited water resources resulting from low rainfall and/or seasonal variation with part of the year being rainless, thin plant cover which

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cannot provide effective protection against erosion, low bio-productivity, variable rainfall leading to recurrent incidents of drought, soft skeletal (i.e. surface deposits showing little development with low content of organic matter) (Dregne, 1992; Kassas, 1995). The most important physical indicators of land degradation in the Mediterranean basin are the state of vegetation and soil (Hill et al., 1994). In arid conditions vegetation provides protection against degradation processes such as wind and water erosion. Vegetation reflects the hydrological and climate variation of the dry ecology. Decreasing vegetation cover and changes in the species composition of vegetation are sensitive indicators of land degradation (Haboudane et al., 2002).

Libya is one of the countries mostly affected by desertification problem, desert and harsh climatic conditions. Limited natural resources such as water, soil and vegetation cover have hampered the expansion of human activity. Libya has very limited water resources (UN, 2005). The global estimates of the water show that per capita of renewable water in Libya has decreased from 500 m^3 in 1950 to 111 m^3 in 1995 and will hit only 47 m^3 in 2025 (Lazald, 2007). Moreover, rainfall is low and fluctuates from year to year thus making the region to be experiencing frequent droughts. Libya suffers from the problem of desertification because of the tyranny of the desert on most of its territory. Though Libya has vast area of land, most of this area of land lies within the warm desert climate that prevails in most of the northern part of the African continent where the desert covers about 98% of its territory (Bin Khayal, 1995).

Desertification is accompanied by deterioration in soil fertility and a change in their physical and chemical properties, and vulnerability to erosion of water (Arab League,

2003). Although climatic factors play an important role in the spread of the phenomenon of desertification, yet human activity causes the deepening of the effects of drought on environmental resources and human beings. Many human factors contribute to the deterioration of environmental conditions and the occurrence of desertification in Libya (El-Tantawi, 2005). Such human factors include the uprooting of trees, forest and shrubs that were protecting the cities from the dust storms. These human factors have led to destruction of soil in some areas thereby making such areas vulnerable to erosion and desertification problems.

The density of natural vegetation in Libya is low, due to low annual rates of rainfall and erratic distribution, particularly in areas of marginal pastures. As a result of lack of vegetation, a lot of pastoral areas in Libya have been under operations of overgrazing. Overgrazing is one of the main reasons that led to the deterioration of the vegetation in these areas in general and also contributed to the elimination of many useful plant species thus making these areas to be under the dangers of desertification (Emgaili, 2003).

Libya has low population, which is mainly concentrated in the northern region mainly in the Jafara Plain and Benghazi Plain. The high concentration of population in northern region has put considerable anthropogenic pressure on the marginal areas. This has resulted in serious environmental problems such as land degradation and low levels of underground water, seawater intrusion into fresh water, degradation of agricultural land and low productivity in many crops (El-Tantawi, 2005). The misuse of soil is one of the main reasons for its degradation and desertification in many areas of agricultural expansion that have been developed in Libya. All these

factors largely contribute to soil degradation in Libya (Libya General Planning Council (LGPC), 2003). The only exception is a narrow coastal strip extends along the Mediterranean Sea and some mountainous areas in the north and south, where rainfall in sufficient quantities is enough for the growth of natural vegetation and cultivation of certain crops and fruit trees (Emgaili, 1995).

In Libya, studies have been undertaken on land use changes (Nwer, 2005; Louhichi, 1999 and Elaalem, 2010); and on climate variations and desertification using RS/GIS tools (Masoud, 2004; El-Tantawi, 2005). Most of these studies are concentrated on Benghazi and Jafara plain (Al-Jadeidi, 1986; Louhichi, 1999; Masoud, 2004; El-Tantawi, 2005; Ammar, 2006; El Trriki, 2006; Elaalem, 2010; Kraium, 2010). Although there are studies that have focused on Jafara Plain, however, there is no study that focused on monitoring and assessment of desertification using remote sensing and GIS in the region. Most of the Libyan populations are concentrated in the north of Libya such as Jafara Plain and the Benghazi Plain. The main reasons for high concentration of population are the availability of important resources such as arable land, water, vegetation and favorable climatic conditions. Furthermore, the fertile land in these areas is more available if compared to the other parts of the country. Based on this background, this study aims to understand the phenomenon of desertification in the North-western region of Jafara Plain and also to identify the vulnerable areas to desertification by applying remote sensing and GIS tools. Findings of the present study will lead to a better understanding of desertification expansion causes and land degradation in the study area. Finally, assessment of desertification severity and causative factors will contribute significantly in identifying vulnerable areas and suggest management implications.

1.2 Problem of the study

Desertification is a worldwide phenomenon that is affecting about one-fifth of the world population, 70% of all dry lands representing about 3.6 billion ha and one-quarter of the total land area of the world (International Fund for Agricultural Development (IFAD), 2006; Abdelfattah et al., 2009). The phenomenon of desertification has attracted much less sustained attention from the international community. Consequently, the rate of advances in this field has been negatively affected (Seely et al., 2008). Every year an additional 200,000 km^2 of productive lands are lost to desertification to the point of yielding nothing (Abahussain et al., 2002; El-Tantawi, 2005; Saad and Shariff, 2011).

Desertification is accompanied by deterioration in soil fertility and a change in their physical and chemical properties, and vulnerability to erosion of water. According to Arab League (2003), the increasing pressure of population on natural resources (such as water, soil, vegetation), poor management, with the absence of controls, lack of maintenance and protection of soil leads to a decline in vegetation cover and salinization of the soil and therefore, the desertification. Even though desertification is not a key issue in the developed countries (Seely et al., 2008), in Africa the problem seems more acute because this processes affects about 46% of the whole Africa (Reich et al., 2004).

Libya is one of the countries mostly affected by desertification problem (UN, 2005). It has very limited water resources. Per capita of renewable water will reduce to only 47 m^3 in 2025 (Lalzad, 2007). Rainfall is low and fluctuated from year to year; therefore, the region witness frequent droughts. Moreover, the warm desert climate

prevails in most of the northern part of the African continent covers 98% of Libya (Bin Khayal, 1995). In general, many parts of Libya suffer from the environmental degradation. However, the parts of the country that are specially affected by environmental degradation are those places of the semi-arid climate, characterized by a fragile ecological system; these places are vulnerable to the causes of environmental degradation and thus desertification. Parts of the study area that are vulnerable to desertification as identified from the satellite images of 2005 is shown in Figure (1.1).

The environmental, social and economic complexities of land degradation make accurate assessment a difficult challenge, especially in dynamic semi-arid environments. Also, the identification of locations of desertification, or those at risk of desertification, is of great importance to authorities that have the responsibility and the power to manage land use (Dragan et al., 2005). Desertification causes a decrease in the volume of agricultural resources and loss of arable land, which ultimately influences the national economy. In recent decades, Libya has witnessed enormous development in various fields, mainly in the sectors of agriculture and industry.

Such development has negative effects on local ecosystems, especially in sensitive and fragile areas. This is due to the change in production patterns, and the need to provide food requirements for the growing population (El-Tantawi, 2005). Consequently, this has led to the intensification of pressure on already limited natural resources, and thus land degradation and desertification.
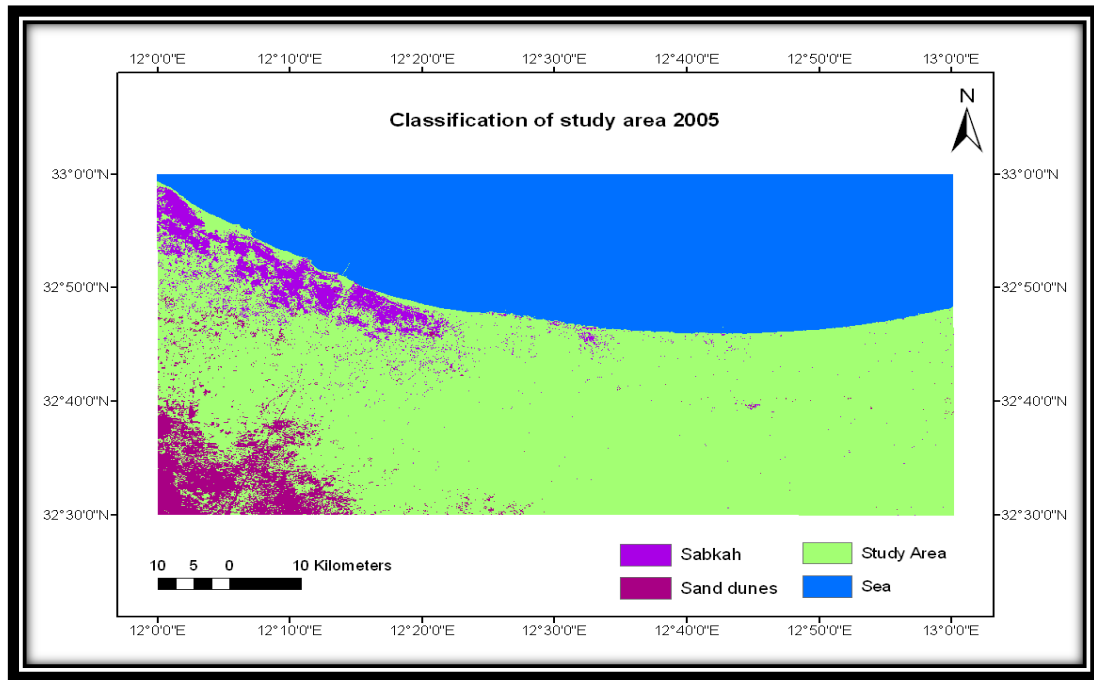
Figure 1.1: The study area established from the satellite images of 2005

        Source: Libyan Center for Remote Sensing and Space Science 2010, modify by Idrisi Kilimanjaro & ArcGIS programs.

Furthermore, the increase of population density, the pressure on pastoral land and conversion of forest areas into irrigated farms especially those that are close to the city of Tripoli are another causes of environmental deterioration. This is often represented by degradation of natural vegetation, soil erosion, increase in the activity of dust storms, the forming and marching of sand dunes, and increase in the salinity of water in the wells (El-Tantawi, 2005).

Consequent upon the growing demand for food resulting from the continuing increase in the numbers of population on one hand, and limited arable land and declining soil fertility on the other, many farmers resorted to implementing agricultural development plans, which do not sufficiently take into account the environmental dimensions. On the horizontal expansion, those plans are applied at the expense of vegetation of natural forests and grasslands. On the vertical

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expansion, they aim to increase the productivity of the same area under cultivation at the expense of the earth stress and soil degradation. The economic importance for the study area represented by the large agricultural value as it is considered the bread basket of Libya in general and the western region in particular.

In order to guaranty and sustain the production of a high percentage of national agricultural products for the entire country, the identification of areas of desertification with a view to assessing its rate and extent is of paramount importance. In addition, there is also a need to understand the mechanisms governing the process of reliable monitoring just as it is necessary to consider effective analysis techniques (UNCCD, 1994). Furthermore, it is equally important to have a clear idea about the situation of the water in relation to environment, to find out the impact of population growth on desertification, to identify the relationship between dry climate in the study area with desertification and land degradation, and finally to determine the contribution of marginal land cultivation towards manifestation of desertification in the region.

As an attempt to provide solutions to the problems identified above, various researchers have conducted several researches in the past. However, some gaps that still need to be filled have been identified from the previous studies. Identification of these gaps is an indication that there is an urgent need for a research to explore the causes of the land degradation as an essential step of proposing some ways to reduce the aggravation of desertification in western region of Libya in general and in Jafara Plain in particular.

1.3   Research questions

1. Do the natural ecosystem components in the study area affect the desertification problem?

2. How far does the interaction between water resources and environmental issues in Jafara Plain?

3. Do human activities contribute significantly in exacerbating the desertification problem in Libya?

4. What is the interrelationship between dry climate, desertification and land degradation in the study area?

1.4   Research objectives

1.4.1   Overall objective (main objective)

The research aims to examine the dimensions of desertification problems and the factors contribute to the severity of desertification in the study area.

1.4.2   Specific objectives

The study seeks to achieve the following specific objectives:

1. To identify the natural ecosystem components that had pronounced effect in influencing the phenomenon of desertification in the study area.

2. To investigate the extent of natural factors (underground water and agricultural land) on desertification.

3. To investigate the extent of human factors in exacerbating the problem of desertification in the region.

4. To evaluate the relationship between climate factor and desertification and land degradation.

1.5   Significance of the study

The significances of the study are as follows:

1.5.1   Its importance for the study area:

Jafara plain is one of the most important areas with concentration of population in Libya; it contains more than 50% of the total population of the country. It also includes the most important agricultural territories. It produces more than half of the country's agricultural production and comprises more than 60% of the total agricultural area irrigated in Libya. It also receives high levels of rainfall if compared with the rest of the country parts. It has suitable soils for agriculture. In addition, the location of most of its plain in the sub-humid and semi-arid territory makes it more interested for the officials and decision makers. Many agricultural projects and settlements were located there for food production and meeting the local needs. However, no considerable attention is paid to the environmental considerations, natural resources scarcity and possibility of exposure to resources depletion and deterioration in this plain.

1.5.2   The subject of study:

The study examines a global problems of great importance, namely desertification and land degradation. These topics have generated considerable interests at local, regional and global levels. This is because desertification and land degradation have negative environmental and economic impacts on society. Consequently, research is needed to identify the reasons for the occurrence of desertification and land degradation; such research will be a fundamental step to suggest some actions and solutions that may help in preventing the occurrence of desertification and land

degradation just as it will assist in mitigating against the development of the hazards to an advanced stage where it might be difficult to control in the future.

1.6   Scope of Research

The study aims to identify the dimensions of desertification problems and their degrees of severity in the study area. Therefore, the study considers numerous issues such as water and soil situation, population growth, overgrazing and deforestation. The study also assesses the relationship between factors that contribute to desertification such as dry climate, periods of humidity and drought, rainfall characteristics, and urbanization in North-Western Libya. The research applied remote sensing and GIS technique to derive land use maps in the study area and also to identify the parts of the region that is mostly vulnerable to desertification. Because area of the study is the most important agricultural part in Jafara Plain as well as in the whole country, thus, development and many productive projects were carried out in the region. In addition, the study covers a wide scope in providing spatial information about the vulnerable areas to desertification and land degradation, and the area that have a good ability for crop growth. Based on the findings of the study, the research will provide some recommendations that will contribute to strategic policy, planning and management of desertification and land degradation not only at local level but also at national and regional levels.

1.7   Structure of the thesis

The thesis is divided into seven Chapters. The components of each chapter are briefly discussed as follows:

Chapter 1 presents the introduction of the study. Various subsections are discussed in this Chapter. These subsections include: background to the study, problem statement, research questions, research objectives, scope and limitations of the study, significance of the study and thesis organization.

Chapter 2 gives the review of the existing literatures on the study area as well as previous related studies on desertification and land degradation. In this chapter, highlights of the previous research works related to monitoring desertification by using remote sensing is undertaken. The main objective of the chapter is to establish the justification for the current study. This is achieved through the review of what researchers have done in the past with a view to identifying the gaps that need to be filled.

Chapter 3: this chapter presents the study area. Various subsections are discussed in this chapter. These subsections include: location of the study area, components of natural ecosystem in area of the study, geology and topography of the region, climate elements, water resources, soil, vegetation and finally the population growth in the study area.

Chapter 4: In this Chapter the procedures of detection of desertification and land degradation in the study area are discussed. In addition, the sources of information,

and methods of data collection as well as analytical techniques of data are highlighted.

Chapters 5 and 6: The results and discussion of results are discussed in these chapters. The results of classification of study area and mapping of land use, the reasons behind the problem for the study area, the relationship between desertification, land degradation and climatic variation and human activities as well as the manifestations of desertification and its hazards in the study area are also presented in these chapters.

Chapter 7: This is the last chapter of the thesis. The summary and conclusions drawn from the research are presented in this chapter. This chapter also includes recommendations for future works.

1.8   Limitations of the study

The limitations of the study are as follows:

i. Inability to procure satellite images captured at the same time and period for several years for better comparison to be made, satellite images of different years must be used; however, these images must be captured at the same time and period. Thus if image of 1989 and 2005 are to be used, these two images must be captured at the same period and time of their respective years. The acquisition of adequate number of satellite images required for the study became more difficult consequently upon the destruction both of the Libyan Center for Remote Sensing and Space Science, the Al-Biruni Center for Remote Sensing owing to the revolution of 17th of February 2011 in Libya. About three or more satellite images were supposed to be

used for the study, but because of the aforementioned problem of image acquisition, only two satellite images were utilized for the study.

ii. Lack of fund to pursue the research is another challenge faced by the researcher. The prohibitive cost of procuring satellite image which is more than about RM 10,000 per sheet accounts for the reason why the area cover in the study had to be limited to the study area shown in Figure (1.1).

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

In the following sections concepts of desertification and land degradation are discussed. This was achieved through the review of relevant literatures on the related works that have been carried out in the past.

2.2   Definition of desertification

According to Dregne (1986), the word desertification has not yet been clearly defined. Various definitions have been given to the term by different authors. For instance, Aubreville (1949) defined desertification as a process of changing a productive land into desert due to ruination of land by man-induced soil erosion. He noted that desertification process in tropical Africa was due to human's activity and not as a result of climatic courses or Sahara spreading courses. In addition, Dregne (1976) also viewed desertification as a process of insolvency of arid, semiarid and sub-humid ecosystems as a result of combined impacts of drought and human's activities.

In the early 1970s, the drought in the African Sahel affected many countries across the southern border of the Sahara as a result of which thousands of people died and millions of livestock were disrupted. In view of the previous critical situation, the United Nations in Nairobi of Kenya organised International Conferences on desertification in August and September of 1977. The conferences attracted many participants from about 100 different nations including international organizations, governmental and nongovernmental organisations. In this conference, the problem of

combating desertification of arid lands was discussed. In spite of this international gathering, researchers did not agree on a standardized and acceptable definition of the term desertification (Dregne, 1986). UNCOD (1977) defined the term desertification as destruction of the biological potential of the land that can lead ultimately to desert like conditions. In another attempt, Dregne (1986) established that desertification was indicated to be the impoverishment of terrestrial ecosystems under the force of human activity. This leads to the deterioration in these ecosystems. The degree of deterioration in the ecosystems can be measured by reduction in productivity of desirable plants, undesirable alterations, accelerated soil deterioration, and increased hazards for human occupancy.

The above stated definitions were quoted by Hellde'n (1988) together with the definition adopted by Rapp (1974) which refers to desertification as the spread of desert-like conditions in arid or semi-arid areas due to climatic changes and human activities. In his words, Hellde'n connotes desertification as "decreasing productivity" which is a key process to implicitly or explicitly be included in all definitions.

In 1992, a summit was held in Rio de Janeiro, Brazil. At the summit, desertification was viewed as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities". After this, many attempts were made to define the term desertification. Eden Foundation (1994) considered the term desertification as "a man-induced process that leads to soil nutrient depletion and reduction of biological productivity".

The International Agreement on Combating Desertification (Paris 1994) defined desertification as reduction or loss of biological or economic productivity resulting from land use or from human activities and habitation patterns. The term desertification is usually stated in a measurable physical, biological conditions or processes which can be used as surrogates for productivity loss.

El-Hassan (2004) finds that desertification is the process of degradation of land and decrease in its productivity. Reasons that lead to this phenomenon can be studied separately.

Finally, the present study conceptualizes the term desertification as the process of degradation of land resulting from climatic variations under human activities leading to decrease in land productivity.

2.3 Causes and factors of Desertification

The occurrence of desertification has been attributed to many factors. However, these factors can generally be categorised into two, which are the climatic variability and human activities. Climatic variability connotes that dry lands have limited water supplies (annual rainfall is less than 100 mm). Rainfall varies significantly during yearly season, which bring about wider fluctuations over years. This leads directly to drought and consequently land degradation, which is a crucial factor for desertification.

On the other hand, many definitions of desertification pay a considerable attention towards human activities as the main cause of desertification. Some of the human

activities that lead to desertification include overgrazing which has been described as the major cause of desertification worldwide, overexploiting land which can happen due to various reasons such as expansion in human population and hence the need for more crops and international economic forces that can lead to short-term exploitation of local resources for export, deforestation (i.e. destruction of vegetation in arid regions, mainly for fuel-wood), poor irrigation practices which would lead to soil salinity that may hamper plant growth and natural and man-made disasters such as floods and droughts, and man-made disasters such as wars and national emergencies can destroy productive land by causing heavy concentration of migrants to overburden an area (El-Hassan 2004).

Furthermore, MEA (2005) established that desertification is caused by a combination of factors that change over time and vary by location. In an extensive assessment of about 150 empirical case studies of desertification, Geist and Lambin (2004) concluded that dry-land degradation and desertification are determined by different combinations of proximate causes and underlying driving forces in varying geographic contexts. Importantly, the rate of dry-land degradation and possible desertification may be further exacerbated by global climate change (MEA, 2005). Due to these differences, a detailed understanding of the complex set of causes and driving forces affecting dry-land cover change in a given location is ideally required before any assessment and policy intervention can be done (Geist and Lambin, 2004). There is an increasing need for research into desertification development and its causes as this can provide an important instruction for desertification control strategies and rational planning of land use in arid and semi-arid areas.

Desertification is thought to be accelerating in some parts of Asia and Africa however, the global data is not good enough to determine trends over time (UNEP, 1991). The little data availability indicated that three broad agricultural land-use systems are prevailing in these dry-lands namely: irrigated, rain-fed cropland and rangeland grazing. According to UNEP (1991), overgrazing of rangelands is the most serious cause of desertification (Kassas, 1995 and Glenn et al. 1998). Furthermore, the driving forces, which cause desertification and the resulting impacts, were often implicitly assumed to be homogeneous, resulting in a poor understanding of how different approaches might be needed in different landscapes and societies.

In the Mediterranean, as in many other countries, agriculture and heavy industries are the main causes of desertification: land degradation due to soil erosion, soil and water salinization and loss of biodiversity. Long-term data and systematic observations are required in order to understand the rate and impacts of desertification, which could help decision-makers in managing natural resources efficiently (Pickett et al., 2007).

2.4   Desertification in Libya

Desertification was first conceptualised as an issue in need of global political attention following the severe drought and associated famine in the Sudano-Sahel region of Africa between 1968 and 1974 (Thomas and Middleton, 1994; Kassas, 1999). According to MEA (2005), desertification is caused by a combination of factors that change over time and vary by location. Due to its particular geographical position and extreme climatic variations, Libya, being one of the African countries, is said to be among the countries that suffers from land degradation and desertification

problems. This fact is captured in some studies that were carried out in the context of Libya. Among them is the study conducted in Benghazi plain area on water resource survey. Previous studies in this part of Libya established the continuous depletion of underground water resources in this region due to the population growth as well as urban development (Al Mahdeawy, 1986; Lama, 1996). In another study by Gefli (1972) a French company, the water resources, the structures, geological formations and the hydrogeology of the eastern region of Libya were explored and recommended various measures for optimum utilization of water resources. Raju (1980) reported on the land situation in Libya, the study emphasised that the water deficit was 12.2 million cubic meters during the years 1975-1976 and it increased up to 82 million cubic meters in 1984 in Benghazi plain. The reports are also available on the geological and geomorphological situation as well as the climate, water resources, soil and natural vegetation of Benghazi plain (Lama, 1996). The above studies on the effects of land use in agriculture on the environment indicated a significant relationship between the excessive use of chemical fertilizers, pesticides, degradation of soil and underground water of Libya, and this fact is supported in the work of Emgaili (1993).

Moreover, Kassas (1999) conducted a study on how to combat the retribution of desertification and land degradation in some Arab countries including Libya based on United Nations efforts. In another tremendous effort by Arab Organization for Agricultural Development (ACSAD), indicators for monitoring desertification in the Arab countries were developed in 2004. Ultimately the causes and consequences of land degradation and desertification in Libya and methods of their control were elucidated. Report of the National Committee from 1999 to 2002 on combating

desertification and crawling desert reviewed the major efforts that have been made in combating desertification. This report briefly explains the major steps taken by Libya government to implement its obligations towards the International Convention to Combat Desertification during this period.

In essence, Libya like many Mediterranean regions also experiences more drought and water deficits that play a major role in the process of desertification. Abufayeda and El-Ghuelb (2001) noted that this deficit will undoubtedly increase in the future in response to the continuous population growth and corresponding increase in water requirements for domestic, industrial and agricultural purposes. Currently, the water demand exceeds the conventional water resources capacities markedly creating an urgent need for integrated water resources management with special focus on non-conventional water resources namely; seawater desalination and wastewater reuse (Wheida and Verhoeven, 2007). This situation of water deficit is becoming more problematic with rapidly increasing population and low rainfall. The high temperatures and low precipitation resulted in the low vegetation cover increased soil erosion and land degradation at large-scale. Consequently, the north west of Libya is being put on highest risk of desertification. Although, some studies on monitoring of desertification in Jaffara Plain of Libya are now nearly consistent with (Al-Jadeidi, 1986; Louhichi, 1999; Al-Rtimi, 2004; Masoud, 2004; El-Tantawi, 2005; Kraium, 2010; Elaalem, 2010), the causes are still being disputed. However, intensive monitoring of desertification process, spatio-temporal pattern, causes and consequences and sound management practice in Jafara Plain area is urgently needed. For instance, the studies of (El-Tantawi, 2005; Wheida and Verhoeven,

2007) reported that desertification in Libya is primarily caused by climate change and anthropogenic activities.

Since desertification is a dynamic phenomenon governed by the potential impacts of surface erodibility and atmospheric erosivity (Thomas et al., 2005, Thomas and Leason, 2005), these dynamism are still not well understood and warrant further attention particularly in Libya. Large areas in Libya are affected by land degradation processes that lead to desertification mainly emerging from conflicts between past and present land uses or between economic and ecological priorities. A particularly important issue in assessing and monitoring desertification is to gain an overview about the affected areas and to connect the global dimension with regional and local processes.

Furthermore, time series and scenarios analyses quantifying the increase in number and extent of sensitive areas at the national scale are lacking in the Mediterranean basin (Salvati and Zitti, 2008; Salvati, et al., 2008 and Brandt, 2005). A permanent assessment of bio-physical and socio-economic conditions leading to land degradation over large areas should therefore be a major concern (Lambin, 1993). In this study, different indicators obtained from various sources (Kosmas, et al., 2000; Kosmas, et al., 1999; Rubio and Bochet, 1998; Salvati and Zitti, 2005), were combined to quantify changes in land sensitivity to degradation. The results will identify areas where sensitivity is increasing over time with a view to indicate the factors involved in this process (Basso et al., 2000).