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Mamdouh Nasr

Assessing Desertification and Water Harvesting in the Middle East and North Africa:

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Policy Implications

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Acronyms and Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
CCD	Convention to Combat Desertification
CEDARE	Center for Environmental and Development for Arab Region & Europe
CIESIN	Center for International Earth Science Information Network
COP	Conference of the Parties
CST	Committee on Science and Technology
DESCON	Consultative Group for Desertification Control
FAO RSU	FAO Remote Sensing Unit
FAO	Food and Agriculture Organization of the United Nations
GIEWS	Global Inforamation and Early Warning System
GIMMS	Global Inventory Monitoring and Modeling Studies
GIS	Geographic Information System
GTZ	German Agency for Technical Cooperation
ICARDA	International Center for Agricultural Research in the Dry Areas
IFPRI	International Food Policy Research Institute
ILO	International Labor Organization
INCD	Intergovernmental Negotiating Committee
INCCD	International Convention to Combat Desertification
MENA	Middle East and North Africa
MS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NOAA	(A satellite operated by the) National Oceanic Atomospheric Administration
PACD	Plan of Action to Combat Desertification
QRDP	Qasr Rural Development Project (at Marsa Matrouh, Egypt)
TM	Thematic Mapper
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNCOD	United Nations Conference on Desertification
UNDCPAC	United Nations Desertification Control Program Activity Center
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization

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Abstract

This study examines four sets of questions:

- What is desertification, and how can its impact on productivity be monitored?
- How extensive is the desertification problem in the MENA region now, and how has it changed over time?
- What is the current status of the water-harvesting techniques used to control desertification in the MENA region?
- What are the main demographic, technical, social, and economic forces driving the problem as it now exists and how will it be influenced by observable trends, particularly in Egypt?

Potential policy actions and their implications are discussed against the background of what is already being done in governmental and non-governmental efforts to address the problem of desertification in the MENA region. At the same time the research explores the economics of water harvesting in the region and its potentials for expanded desert utilization. The study presents environmental data on each of the countries in the MENA region and on the region as a whole, which was collected by a satellite remote sensing system over the last 17 years. The images of the MENA region produced by the NOAA satellite showed no alarming damage to vegetation – quite the opposite: we estimated that the vegetational boundary has expanded into the desert in most of the MENA countries due to human actions.

Key words: Desertification; Satellite Remote Sensing; Water Harvesting; Technical, Social and Economic Parameters.

Kurzfassung

Diese Studie präsentiert, diskutiert und analysiert (a) den Begriff der Desertifikation und Methoden der Überwachung von Produktivitätsbeeinträchtigungen durch Desertifikationsprozesse, (b) das Ausmaß der Desertifikationsprobleme in der Region des Nahen Ostens und Nordafrikas (MENA), (c) die Techniken des "Water Harvesting", die zur Bekämpfung dieser Probleme verwendet werden, sowie – am Beispiel Ägyptens - (d) die technischen, sozialen und ökonomischen Determinanten des Desertifikationsproblems.

Darüber hinaus werden aktuelle politische Handlungsalternativen und ihre Implikationen für Regierungs- und Nichtregierungsorganisationen in der MENA Region diskutiert und Themen für zukünftige wissenschaftliche Untersuchungen vorgeschlagen.

Die vorliegende Studie basiert auf NOAA- Satellitendaten für die einzelnen Länder der MENA Region, die den Zeitraum von 1982 bis 1997 abdecken.

Die Daten machen deutlich, daß die Vegetationsdichte der MENA Rgion in den letzen 17 Jahren keinen Schaden erlitten hat. Im Gegenteil, die Vegetationsintensität nahm aufgrund positiver anthropologischer Aktivitäten zu.

1 Introduction

New deserts are forming in some areas of the world (UNEP, 1984). This process is referred to as “desertification”. For most people, the term conjures up an image, an emotive picture of inexorably shifting sands encroaching on valuable farmland (Forse 1989). But is the desert really expanding? An increasing number of scientists are now arguing that the image associated with “desertification” is a mirage.

There is no general consensus regarding the definition, causes, or impact of desertification. Desertification has been defined in many different ways by researchers in different disciplines, which have included soil scientists, hydrologists, agronomists, veterinarians, economists and anthropologists. Most definitions of desertification therefore vary according to the judgment and expertise of the researchers involved. Whereas some researchers consider desertification to be a great danger to the sustainable development of arid and semi-arid areas, others doubt that the phenomenon occurs at all. Researchers’ differences of opinion regarding desertification are due mainly to the lack of an overall concept, the dearth of information available at both the global and regional levels and the differences between the objectives and interests of the countries in the north and of those in the south, i.e. the ones mainly affected.

The problem of desertification in arid and semi-arid areas can be traced back through several centuries. There has always been a correlation between long-term changes in climate and changes in human activities. As long as the population density of both men and livestock in a desertification-endangered area remained sufficiently low, the ecological consequences of human activities remained relatively insignificant or were concentrated within a very limited area.

In regions where food security and poverty alleviation are priorities, such as the Middle East and North Africa (MENA) region, the primary emphasis regarding land is its availability, the abatement of land degradation, and efficient land and water management are of vital importance. The message currently being spread by the FAO is to encourage countries in arid and semi-arid areas to identify reasons for land degradation.

Few researchers argue that most MENA countries have appropriate technologies to combat desertification - such as rainwater harvesting -, but that the technologies are not used sufficiently due to insufficient knowledge of the socioeconomic contexts, incorrect identification of the causes of the arid land problems and ineffective management of natural resources, i.e. water.

The study addresses four questions:

- What is desertification, i.e. describing the concept and how to monitor productivity impacts of desertification processes?
- What is the magnitude of desertification problem in the MENA region, both current and in the past?
- What is the status of water harvesting techniques used to control desertification in the MENA region?
- What are the major demographic, technical, social, and economic driving forces behind the observed phenomena and trends? (With special references to Egypt)

Policy actions and implications are discussed against the background of what is being done in the MENA region to address desertification problems, both governmental and non-governmental efforts.

2 Concepts and Techniques for Identifying Desertification Processes

2.1 What is Desertification ?

The phenomenon of desertification is very old, but national and international awareness of it and the desire to control it are very recent. In the public mind, desertification is often associated with the idea of 'desert advance'. In the 1970s, there was great concern that the Sahara desert was advancing into the non-desert lands of West Africa.

The definition of desertification agreed upon in 1977 at the United Nations Conference on Desertification (UNCOD) in Nairobi is as follows: "Desertification is the diminution or destruction of the biological potential of land, and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems, and has diminished or destroyed the biological potential, i.e. plant and animal production, for multiple use purposes at a time when increased productivity is needed to support growing populations in quest of development."[1]

When, in various parts of the world, the first attempts were made to carry out a quantitative assessment of desertification and to implement various practical recommendations of the Plan of Action to Combat Desertification (PACD), this definition was found to be inadequate and insufficiently operational. A new, more precise definition was required to distinguish between desertification and other problems of climatic change.

A numbers of definitions have been suggested by various scientists, scientific institutions and implementing agencies. Based on special studies and extensive discussions at the UNEP Consultative Meeting on the Assessment of Desertification in Nairobi in 1990, the following new definition was suggested: "Desertification is Land Degradation in Arid, Semi-arid and Dry Sub-humid Areas resulting from adverse human impact. Land in this concept includes soil and local water resources, land surface and vegetation or crops. Degradation implies reduction of resource potential by one or a combination of processes acting on the land."[2] This definition implied agreement on a tool for assessing and combating desertification that would be more suitable operationally.

[1] UNEP, Status of Desertification and Implementation of the United Nations' Plan of Action to Combat Desertification, UNCED Part I, 1996.
[2] UNEP, 1996 (see No. 1 above).

The UNEP Panel of Senior Consultants (April 1991) and the Governing Council of UNEP (May 1991) underscored “the need for further refinement of the definition, taking into consideration recent findings about influence of climate fluctuations and about the resilience of soils”.

The following definition of desertification was agreed to by the world’s leaders at the 1992 Earth Summit and adopted by the United Nations Convention to Combat Desertification (UNCCD): “Land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities”[3]. This definition is now widely regarded to be the authoritative definition of desertification.

2.2 Towards a Definition of Desertification

Since the in-depth investigation of desertification phenomena requires the expertise of researchers from a variety of disciplines, including soil scientists, hydrologists, agronomists, veterinarians, anthropologists, and economists, desertification has been defined in many different ways by these disciplines. Most of these definitions of desertification are therefore colored by value judgments, personal experience, and/or disproportionate weighting of some dimensions and neglect of others. It may thus be said that we still do not have a sufficiently specific scientific definition of desertification.

Some researchers consider desertification to be a process of change, while others view it as the end result of a process of change[4]. This distinction represents one of the main points of disagreements concerning the concept of desertification. When considered to be a process, desertification has generally been viewed as a series of incremental changes in biological productivity in arid, semi-arid, and subhumid ecosystems. When considered as an end result, desertification refers to the prevalence of desert-like conditions in areas once green. Although dozens of definitions exist, one point on which they all agree is that desertification is to be viewed as an environmentally adverse occurrence. Glantz and Orlovsky (1983) reviewed various definitions focusing on the form of change: desertification considered to be a deterioration of ecosystems (e.g. Reining, 1981), a degradation of various forms of vegetation (e.g. Le Houerou, 1975), the destruction of biological potential (e.g. UNCOD, 1978), a reduction of productivity (e.g. Kassas, 1977), a decay of a productive system (e.g. Hare, 1977), an alteration in biomass (e.g. UN Secretariat, 1977), an intensification of desert conditions (e.g. Meckelein, 1980), or an impoverishment of ecosystems (e.g. Dregne, 1976). Some other definitions focus on what is changed in the soil; (e.g. salinization), vegetation (e.g. reduced density of biomass), water (e.g. waterlogging), or air (e.g. increased albedo).

[3] United Nations Convention To Combat Desertification, published by the Secretariat for the Convention to Combat Desertification (CCD), Bonn, Germany, 1999.
[4] Glantz, M.H., and Orlovsky, N. S., Desertification: A review of the Concept, Desertification Control Bulletin 9, CIESIN organization, 1983.

There is no consensus regarding the areas where desertification can take place. Many researchers identify arid, semi-arid, and subhumid areas as places where desertification can occur or where the risks of desertification are highest. Others refer to the extension, encroachment, or spread of desert characteristics into non-desert regions.

With respect to the factor of time, some definitions refer to desertification as a permanent process. Others imply that desertification may be reversible, because the term “irreversible” is generally used in reference to situations in which the costs of reclamation are greater than the return to be expected from a known form of land use.

The above-mentioned review of definitions shows that defining desertification conveys some impression of the difficulties involved in arriving at a definition of desertification. The following discussion examines some aspects that should be taken into consideration in suggesting a definition of desertification in arid and semi-arid areas. While distinguishing between desertification and land degradation is still difficult, it is made easier by the following criteria:

- Pure desert must be considered dry-lands with no plants and organic matter in the soil. Thus, pure desert areas should not be considered desertified.
- It is necessary to distinguish between desiccation (long-term drought) and desertification. The term drought is used to refer to an inter-annual fluctuation in precipitation in which there is a relative lack of rainfall for a period of one to four years, whereas desiccation is used to denote a protracted drought that has continued for a decade or more and may be considered a kind of climate change.
- It is also necessary to distinguish between desertification and land degradation. Land degradation refers to a decline in the long-term productive potential of soil (Lal, 1990; UNEP, 1982; UNCED, 1992).
- Net degradation occurs whenever degradation processes significantly exceed nature’s restorative capacity. One obvious indicator of land degradation is a continuous decline in soil productivity (production per unit land), but a decline in one year followed by increase in the next is not indicative of land degradation.
- Land degradation may also be caused by too much water (flooding), which may result in soil erosion, and too little water (drought).

As there is still a good deal of confusion regarding the definition, diagnosis, and measurement of desertification, it may be timely to raise a few questions, such as: Why not simplify the matter and define desertification as the extension of desert margins into non-desert areas? In this case, however, we would have to deal with at least 30 to 40 years of data, in order to investigate shifts in desert margins. Why not say, that almost all the forms of degradation that we have observed, are by definition land degradation, rather than desertification? Why not say that all processes acting against sustainable land use are degradation processes? These suggestions call not for a redefinition of the problem, but simply for the use of suitable terminology.

2.3 Problems and Indicators Related to Processes of Desertification

Problems posed by land degradation processes can hardly be generalized across land-use zones. Land degradation problems differ in range-land, rainfed, and irrigated areas[5]. According to UNEP, the main desertification problems in range-land areas are: overgrazing, shrub clearing, soil erosion, and cultivation. In the desertification of rainfed areas, soil erosion is the principal problem. The main desertification problem in irrigated agriculture is “salinization” or “alkalinization”.

(a) Overgrazing refers to the practice of allowing a much larger number of animals to graze at a location than it can actually support. This includes: (a) selecting inappropriate times for grazing, often too soon after the beginning of rainfall, (b) overstocking, (c) failing to actively seed, and (d) failing to adjust existing or traditional land-use and grazing rights. This problem is observed in almost all MENA countries.

The main **indicator** of overgrazing is the “disappearance of range-lands” because animals usually eat the most palatable plants first and the least palatable ones last, thus selecting and ensuring the dominance of relatively unpalatable species.

(b) Shrub clearing is caused by the practice of constantly using woody plants as a source of energy for human needs, as may be observed, for example, in Egypt and Yemen.

A visible **indicator** of shrub clearing is the “disappearance of shrubs” in areas that can support woody vegetation.

(c) Soil erosion results from the uprooting of shrubs, which leads to the destruction of the soil structure and thus to accelerated erosion of the soil by wind and water. Soil infiltration of rainwater decreases, and surface runoff increases. Examples of this type of desertification are to be seen in Egypt, Saudi Arabia, and Yemen.

One clear **indicator of** soil erosion is the formation of drought watercourses in the depressions of wadis.

(d) Over-cultivation of food or field crops in areas that ought to have been used only for grazing over a long time of period. The soil structure is destroyed by ploughing, particularly in

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[5] German Foundation for International Development (DSE), FAO, GTZ, UNESCWA, Resource Conservation and Desertification Control in The Near East, Report of the International Training Course, Germany and Kingdom of Jordan, 1989.

dry years, because the surface remains bare of vegetation. **Examples** of over-cultivation of grazing areas and marginal lands are to be found in Sudan, where population pressure plays an important role and no alternatives are available, and in Yemen, Syria and Jordan, where some range-land on steep slopes is ploughed. In countries such as these, population pressure makes it difficult or impossible to allow land to lie fallow.

A clear **indicator** of rainfed cultivation in an area that should actually be used for grazing is the occurrence of "dust storms", which means a reduction of range-land at the cost of arable land.

Salinization is the main desertification problem in irrigated agriculture. Salinization involves a number of interrelated processes occuring in the soil, for example waterlogging, increasing salt content, and alkalinization, in which some nutrients can no longer be absorbed due to the increasing pH-value of the soil. This problem is caused by the overuse of water through unsuitable irrigation techniques, accompanied by inefficient drainage systems. This type of desertification is to be seen in some of the irrigated agriculture in Iraq and Egypt.

2.4 Global Status of Desertification

The world's total drylands area has been estimated three times: by UNCOD in 1977, and by UNEP in 1984 and again in 1991. These estimates were prepared using slightly different methodologies and different climatic data sets[6]. The 1991 estimates of the total dryland areas were used by UNEP as the basis for the latest assessment of global desertification in 1991 (Table 1). However, "assessment of the current global status of desertification has shown that accurate hard data, which would allow it to be stated with some preciseness to which degree and with what rate of desertification is taking place in various parts of the world, are still lacking"[7].

[6] UNEP, 1996 (see No. 1 above)
[7] UNEP, 1996 (see No. 1 above)

Table 1: Status of global desertification

Types of Degradation	Area (millions of hectares)	Relative Importance (%)
1. Irrigated areas	43	0,8
2. Rainfed agricultural areas	216	4,1
3. Rangeland areas	757	14,6
4. Total drylands degraded by human factors	1.016	19,5
5. Rangeland with vegetation deterioration without soil deterioration	2.576	50,0
6. Total degraded drylands (4)+(5)	3.592	69,5
7. Non-degraded drylands	1.580	30,5
8. Total dryland area (6)+(7)	5.172	100

Source: UNEP Desertification Status Report, 1996.

The reported results suggest that present desertification directly affects about 3.6 billion hectares, representing 70% of all dryland, and about one-sixth of the world's population (UNEP 1996). About 43 million ha of irrigated land (0.8% of all dryland) are affected by various degradation processes, mainly waterlogging, salinization and alkalinization. Soil scientists have established that the world is now losing, about 1.5 million ha of irrigated land each year. Nearly 216 million ha of rainfed cropland (4.1% of all dryland) are affected by various degradation processes, mainly soil erosion through water and wind, depletion of nutrients and physical deterioration. It is estimated that the world loses about 7 - 8 million ha of rainfed cropland each year. About 3.333 million ha of rangeland (64% of all dryland) are affected by degradation, mainly by degradation of vegetation, which is accompanied by soil degradation consisting, mainly of erosion on some 757 million ha.

2.5 International Efforts to Combat Desertification

In 1977, the United Nations Conference on Desertification (UNCOD) adopted a Plan of Action to Combat Desertification (PACD). Despite this plan, unfortunately, the United Nations Environmental Program (UNEP) concluded in 1991 that the desertification problem in drylands had intensified[8]. Implementation of the PACD had suffered under funding constraints.

As a result, the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, called upon the United Nations General Assembly to establish an Intergovernmental Negotiating Committee (INCD) to prepare, by June 1994, a Convention to Combat Desertification in affected countries, particularly in Africa.

[8] United Nations Convention To Combat Desertification, Published by the Secritariat for the Convention to Combat Desertification (CCD), Germany, 1999.

The INCD completed its negotiations in five sessions. The Convention was adopted and opened for signature in Paris in 1994. The convention entered into force in 1996, and some 120 countries are now Parties[9]. The Conference of the Parties (COP), which is the Convention's supreme body, held its first session in Rome in 1997. The COP held its second session in Dakar in 1998, launching a global mechanism to obtain adequate financial and technological resources.

[9] CCD, 1999 (see No. 8 above)

3 Current Status of Desertification in the MENA Region and its Control Using Rainwater Harvesting

3.1 Land, Water and Population in the MENA Region

The Middle East and North Africa region extends from the Atlantic Ocean (Morocco) in the west, to Iraq in the north, to Egypt in the south, and to Yemen and Oman in the southeast. It comprises 17 countries with a total area of 9,5 million km², which represents about 7% of the world's total land area.

Population growth in the MENA region averaged 3.3% in 1995, the world's highest rate of growth. Urban population has doubled in recent years to 54% of total population. The region's population totaled about 231 million in 1995. The population density is lowest in Libya, with 3 inhabitants per km², and highest in Bahrain, with 853 inhabitants per km².

The water situation has been described as "precarious" in terms of both quality and quantity. Four of the 17 MENA countries consume more than 100% of their renewable water resources. Rainfall in the region averages 300 mm per year. At least 400 mm per year is needed for successful agriculture. Rainfall ranges from a maximum of 1500 mm/year in Yemen, Lebanon, Morocco, Algeria, and Tunisia to a minimum of 5mm/year in the north of Libya. It is estimated that MENA groundwater reserves amounted to 15,3 km³ in 1987[10]. In some cases, neighboring countries in the region share groundwater basins, e.g. i) Algeria and Tunisia, ii) Egypt, Libya and Sudan, iii) Kuwait, Bahrain and Saudi Arabia. The MENA region's present rate of groundwater withdrawal cannot be considered sustainable over the long run since it far outpaces the rate of replenishment and will relatively rapidly deplete the aquifers. Surface water in the MENA region flows in 50 sustainable rivers, including all the branches of the Nile, Euphrates and Tigris Rivers. Since many of these rivers are shared by two or more countries, water availability in those countries depends on water coming from outside. The internal renewable water resources per inhabitant in the MENA are among the lowest in the world. The region's average is 1016 m³/year per inhabitant, compared with about 7000 m³/year per inhabitant for the world overall[11].

[10] K.F. Saad, M. Shaheen, Evaluation of Water Resources in the Arab World, Arab Center for Dry-land Studies, International Institute for Hydrological and Environmental Engineering, Paris, 1988.
[11] Food and Agriculture Organization of the United Nations (FAO), Irrigation in the Near East Region in Figures, Water Report No. 9, Rome, 1997.

The structure of water demand among individual water users is 1 m^3 of drinking-quality water per year, 100 m^3 of water per year for domestic purposes and a further 1000 m^3 of water per year for the production of food, making a total of 1101 m^3 per person per year. In 10 of the 17 MENA countries, the internal renewable water resources per inhabitant are below 1000 m^3/year, and the countries are consequently considered to be water-scarce countries. Four countries, Egypt, Oman, Libya and Morocco, are considered to be water-stressed countries, as they have 1000- 1667 m^3/year per inhabitant. With internal renewable water resources in excess of 1700 m^3/year per inhabitant, Iraq, Lebanon and Syria are considered to be water-abundant countries. In the MENA region, 84% of water withdrawals are directed to agriculture. Iraq has the highest level of water withdrawal for agriculture (97%), as a high percentage of the cultivated area (95%) is irrigated. Kuwait has the lowest level of water withdrawal for agriculture (38%), as it has practically no internal renewable water resources.

3.2 The Extent of Aridity of the MENA Region

According to UNESCO, arid regions are defined as areas where potential evapo-transpiration is much greater than precipitation. Table 2 shows the extent of aridity in the MENA region as reflected in rainfall data. It also shows that arid and semi-arid areas amount to about 96% of the North African part and 95% of the Asian part of the MENA region.

The most common features of arid and semi-arid lands in the region are[12]:

- Erratic and unpredictable rainfall with great seasonal and annual fluctuations;
- Average annual evapotranspiration far exceeding precipitation;
- Water-constrained agricultural production;
- Extensive fluctuations in temperature, and rainfall patterns, and in the degree of aridity.

[12] Omar Joudeh, "Integration of Water Harvesting in Agricultural Production", in the FAO Proceedings of the Expert Consultation about "Water Harvesting for Improved Agricultural Production", Water Report 3, Rome, 1994.

Table 2: Extent of aridity in the MENA region

Sub-region	Total Area (1000s of km²)	Amount of Rainfall				A + B as % of Total
		Less than 100 mm (A) Arid Areas		100- 400 mm (B) Semi- Arid Areas		
		Area (1000 km²)	%	Area (1000 km²)	%	
North Africa (1)	5 751	4 864	85	653	11	96
Near East (2)	3 705	3 033	79	589	16	95
Total MENA	9 456	7 897	84	1 242	13	97

Source: A. Arar, Optimization of water use in arid areas, Arab Consult, Jordan, 1993
(1) Egypt, Libya, Tunisia, Algeria, and Morocco.
(2) Bahrain, Iraq, Israel, Jordan, Lebanon, Kuwait, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen

The MENA region's system of agricultural production is characterized by the following features:

- Low infiltration of rain water into the soil due to the erratic nature of the rainfall and the relatively low soil permeability;
- Low soil fertility and content of organic matter;
- High soil salinity and alkalinity;
- Poor vegetative cover and grazing lands;
- Low soil productivity due to the shortage of water and low nutrient availability;
- High soil erodibility.

3.3 Lack of Sound Desertification Statistics

The information base on the current magnitude of and trends in desertification in the world, particularly in the MENA region, is very poor. The data needed to classify land is available for only very few areas, and for very few years (UNEP, 1996). For most of Africa, and particularly for the African part of the MENA region, very little is known about the extent of land degradation (Ahlcrona, 1988; UNCOD, 1997). In Africa, where it is difficult to obtain data, attempts to quantify degradation, even in small areas, have thus far failed to come up with sound estimates (Ahlcrona, 1988; Olsson, 1985).

There is no comprehensive assessment of the degradation of irrigated land, rainfed cropland, or rangeland in the region. There are no time-series data available on the development of desertification in the region. The only information available for the region, is the estimates provided by UNDCPAC/ Dregne for 1992. Many of the figures are derived from responses to a questionnaire sent to 100 countries by UNEP in 1982. The answers to that questionnaire probably mean very little, says Swift (1984). “In Africa, governments were completing it in many cases at the height of a drought,”, says Nelson (1989). “Experts even from sophisticated governments say they had great difficulty answering the questions. They had little of the data that they were asked for. They were no proper guidelines for how to answer critical questions about the degree of desertification of land,”, says Forse (1989).

In spite of the deficient data, we used UNDCPAC/Dregne[13] estimates for 1992 to quantify the magnitude of desertification in the MENA region, because these estimates are the only source of information available about the problem in the region. For the purposes of comparison, we tried to obtain data from the satellite remote sensing system and selected local research reports and studies relating to the region.

Most of the reports on desertification were based on Dregne and Chou (1992) estimates, which were derived from UNDCPAC (1987), reflecting conflicting definitions. One example of misleading statistics on desertification is the claim by UNDCPAC that 35 percent of Earth’s land area is threatened with desertification. This 35 percent, however, is the area that is arid, at least half of which is very arid,: by UNDCPAC’s own acknowledgment, this zone is not in danger, as about half of it is too arid for any form of agriculture[14].

This also applies to the MENA region, most of which is hyperarid (62%, see Table 3), consisting of pure desert, and far too arid for any form of farming. Another example is the misuse of terms such as “desert expansion” in some international debates in spite of the assurance by national authorities that the most serious problems in semi-arid areas do not occur at desert margins (UNCOD Plan of Action, 1977). Few people live in such areas, and the most destructive forms of land use, such as overcultivation and overgrazing, do not take place there[15].

An additional example is that in Algeria, Saudi Arabia, and Morocco, the problem was seen as desert expansion. The countermeasure, therefore, was the planting of sand dunes, which is costly. Warren and Agnew (1988) say that active sand dunes seldom threaten valuable land. Even some areas covered by active dunes has been shown to be stable. The same difficulty was encountered by the United States Soil Conservation Service, when it plotted damage to farmland in the drought and recession years of the 1930s. Many areas seen then as irreparably damaged (Held and Clawson, 1965) are producing record crops today.

[13] Dregne, H. E., and N.T. Chou, Global Desertification Dimensions and Costs, in Degradation and Restoration of Arid Lands, Lubbock: Texas Tech. University, 1992.
[14] Warren, A., and C. Agnew, An Assessment of Desertification and Land Degradation in Arid and Semi-arid Areas, International Institute for Environment and Development, Paper No. 2, London: Ecology and Conservation Unit, University College, 1988.
[15] See Warren, A., and C. Agnew, 1988.

It stands to reasons that, a selected measure of the desertification process depends upon the definition used, and that the definition itself is a type of diagnosis of the desertification process. The more precise a diagnosis is, the more effective the selected measure will be. Warren and Agnew say that if the diagnosis is falling productivity due to over-exploitation, over-grazing, or over-watering, then the measure is better management of land and water. If the problem is seen as climatic change in a certain area, permanent withdrawal is called for. If the problem is seen as near-complete devegetation, in the absence of a climatic change, re-seeding or re-planting is suitable treatment. If the problem is seen as expansion of the desert margin, then some kind of holding-line might be appropriate treatment. Lastly, if the problem is thought to be drought for no more than two or three years, food aid may be adequate.

Since desertification is a complex process, involving a mix of conflicting definitions, causes and effects, no single indicator alone can adequately reflect the interaction of its several components.

3.4 The Magnitude of and Trends in Desertification Problems in the MENA Region

The degree and type of desertification varies from one country to another within the region. This section describes the types and magnitude of desertification problems within each country of the MENA region. According to the United Nations Desertification Control Program Activity Center (UNDCPAC), the main desertification processes observed in the region are soil degradation, water and wind erosion, salinization and waterlogging, which of course affect land use. Land-use figures indicating the areas of irrigated agriculture, rainfed cropland, and rangeland in the MENA region are shown in Table 3, and a country-by- country breakdown is provided in Tables 3- 6 in the annex.

Most (62%) of the MENA region is hyperarid. Five north African countries (Egypt, Libya, Tunisia, Algeria, and Morocco) and twelve countries of the Middle East (Bahrain, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, and Yemen) lie entirely in arid areas. Over half of Saudi Arabia is hyperarid.

Table 3: Estimated land use in the MENA region

Land Use	**Area (in 1000's of ha)**	**%**
Irrigated agriculture	7.372	0,77
Rainfed cropland	29.981	3,12
Rangeland	330.633	34,37
Hyperarid land*	593.866	61,74
Total drylands	961.852	100,00

* Hyperarid= extremely arid
Source: Computed from UNDCPAC/ Dregne 1992, UNEP 1996.

UNDCPAC/-Dregne (1992) estimates of the desertification status of the irrigated land, rainfed cropland, and rangeland in the MENA region as a whole are shown in Table 4, and a country-by-country breakdown is provided in Tables 3- 6 in the annex. Unfortunately, there are no country-specific studies available to compare Dregne's assessments of desertification in the region.

Each hectare of desertified land has been categorize into one of four classes according to its degree of desertification (slight, moderate, severe, very severe). Slight, moderate, and severe desertification are usually reversible, but very severely degraded land cannot at present be rehabilitated cost-effectively. Land categorized as slightly desertified shows little or no degradation (less than 10 percent loss in potential yield), moderately desertified land shows 10-25% degradation, severely desertified land 25%- 50% degradation, and very severely desertified land more than 50% degradation.

The main indicator of degradation in the region's irrigated areas is salinity, combined with waterlogging. According to the UNDCPAC estimates, most of the affected irrigated areas lie in Iraq (71%), Saudi Arabia (63%), Tunisia (33%), and Egypt (30%) (Table 4 in annex).

These problems are due to bad irrigation management (over-irrigation) in the absence of adequate drainage systems. Of the total area affected of 2,7 million ha (37%), 231,000 ha (3%) are very severely degraded, while the degree of degradation of the rest (97%) is reversible. Despite the doubts about the reliability of theses estimates (see section 3.2), they show that the magnitude of the problem in the MENA region is very limited.

Moreover, these estimates say nothing about current trends or future developments. Estimated trends in the development of yield, area harvested, and production of grain during the 1975- 1997 period show an increase accompanied by reduced application of fertilizers. This result offers some relief from the alarm caused by UNDCPAC estimates and calls for more precise studies based on surveys in combination with satellite remote sensing systems.

Table 4: UNDCPAC (1992) estimates of desertification in irrigated, rainfed cropland, and rangeland areas of the MENA region

Land Type	Total Area (1000's of ha)	Degree/Percentage of Desertification					
		Slight	Moderate	Severe	Very Severe	Total, incl. Moderate	%
Irrigated	7,372	4,652	2,021	468	231	2,720	37%
Rainfed	29,981	8,226	19,134	2,458	163	21,755	73%
Rangeland	330,633	50,123	104,025	175,301	1,184	280,510	85%
Total	367,986	63,001	125,180	178,227	1,578	304,985	83%

Source: Computed from UNDCPAC/ Dregne, 1992, UNEP 1996.

Rainfed cropland represents only 3 % (almost 30 million ha) of the MENA region's total drylands, of which about 22 million ha (73%) are estimated by UNDCPAC to be degraded. The scope of degradation of rainfed cropland is greatest in the countries of northern Africa: Algeria (93%), Morocco (69%), Tunisia (69%) and, exceptionally, Egypt (10%). The extent of degradation in the countries of the Middle East, i.e. Iraq (72%), Syria (70%), is higher than that in the Arab Golf Countries,: Oman (50%), Qatar (25%), and Bahrain (20%). According to the UNDCPAC estimates, only 163,000 ha (0.5%) are very severely degraded, and the rest can be rehabilitated. Even if these estimates are imprecise, the magnitude of the problem is very limited, particularly given that most of the degradation has occurred in the past 50 years.

According to the UNDCPAC/ Dregne estimates, the degradation of rangeland is more extensive than that of irrigated or rainfed areas. It is estimated that 85% of the rangelands in the MENA region are degraded. The principal cause of degradation is overgrazing, combined with the cutting of woody species for use as fuel. Algeria, Iraq, Lebanon, Oman, and Qatar have the highest percent of desertified rangeland (90%), whereas Bahrain has the lowest (20%).

Modification of UNDCPAC/ Dregne Estimates of Desertification in the MENA Region

Since desertification does not occur apart from drought, we consider irrigated areas to be productive, cultivated areas suffering from salinity or waterlogging problems due to bad management of irrigation and/or drainage. These kinds of problems, which have to do with water management, and not with drought or directly with the soil, may be considered alarm signals that improved management of irrigation is overdue. This paper considers the irrigated areas to be slightly degraded, and not desertified. This is true as long as it can be demonstrated that there has been no real decline in soil productivity, even though there may have been slight declines in certain years.

Also, the livestock-carrying capacity of most rangelands in the MENA region is limited more by the lack of drinking water than by a lack of feed (see the results of the Egyptian case study). The shortage of water compels farmers to monitor the grazability of rangelands, so that even if overgrazing does in fact occur in some places, Dregne's estimates that 85% of the MENA rangelands are desertified seems to be very high[16].

Nor should we ignore the fact that, in order to cope with the scarcity of water, Bedouins in the MENA region, who have long had to struggle to survive, have devised means and ways of finding alternatives and putting their experience to use, for example by treating the margins of their rangelands, cultivating them with some grass species to protect them against erosion and harvesting rainwater to increase their water supply[17]. Based on the above considerations, we consider 50% of Dregne's assessment of rangeland desertification to be more realistic.

In light of the above, Dregne's assessments of desertification in the MENA countries may be modified by: (a) excluding the irrigated area as only slightly, or not at all, desertified, and (b) assessing the proportion of rangelands desertified at 50%, instead of at 85% as Dregne did. The results are shown in Table 5.

Table 5: Modified UNDCPAC estimates of desertification in irrigated, rainfed cropland, and rangeland areas of the MENA region

Land Type	Total Area (1000's of ha)	Degree/Percentage of Desertification					
		Slight	Moderate	Severe	Very Severe	Total incl. Moderate	%
Irrigated	7,372	7,372	0	0	0	0	0%
Rainfed	29,981	8,226	19,134	2,458	163	21,755	73%
Rangeland	330,633	165,316	61,333	103,323	661	165,317	50%
Total	367,986	180,914	80,467	105,781	824	187,072	51%

Source: Own proposal.

[16] The newsletter issued by the "Office of Dry-lands Studies" of Arizona University in 1979, estimated global desertification to be only half of Dregne's estimates.
[17] Nasr, The Technical, Social and Economic Aspects of Water Harvesting and Water Supply in Rainfed Desert Farming Systems, Project No. I-12, National Agricultural Research Program (NARP), funded by USAID, Ministry of Agriculture and Land Reclamation, Egypt, 1992-1994.

3.5 Costs of Land Degradation in the MENA Region

Assessments of land-degradation costs capture costs of two kinds. The first is the income foregone due to prior land degradation. The second is the cost of preventing further degradation and rehabilitating the land. In preparing this assessment in 1996, UNEP assumed the following basic figures for the average yearly income foregone due to desertification, at 1990 prices[18]: US-$-250 per ha of irrigated land; US-$-38 per ha of rainfed cropland and; US-$-7 per ha of rangeland. These figures represent a productivity loss of, approximately, 40% as the land is at least moderately degraded.

Based on the above figures and taking into account the modified assessment of the total areas affected by degradation in each of the land-use categories shown in Table 5 (0 ha of irrigated land, 22 million ha of rainfed cropland and 165 million ha of rangeland), we estimate the annual average income foregone in the MENA region due to desertificationat US-$-1.98 billion (Table 7). Since currently available assessments of desertification are imprecise, this figures must be considered to be only a very general indication of the income foregone by the region as result of desertification.

As mentioned above, the costs of rehabilitating land include both the costs incurred to stop further degradation and the costs of restore the land to its original, or at least to an improved condition. Drylands slightly affected by desertification require certain corrective measures to prevent further degradation and to sustain their productivity. Severely or very severely degraded drylands require serious efforts and expense to rehabilitate and return to productive use. The rehabilitation of eroded rainfed cropland requires perhaps five to ten years, and that of rangeland needs 50 years[19]. The most recent attempt to obtain figures indicating the costs of direct anti-desertification measures (preventive, restrictive and rehabilitative) was made by UNEP in 1992, based on the 1991 assessment of land degradation. From data provided by a large number of relevant projects in various parts of the world, UNEP derived global average figures for such costs (Table 6).

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[18] UNEP, Financing the Plan of Action to Combat Desertification, Desertification Report, Part IV, 1996. This report used the UNEP/Dregne assessment of desertification published in 1992. Due to the lack of data and information at both the global and regional levels, Dregne set a single figure on the amount of income foregone, regardless of whether the land involved was irrigated land, rainfed cropland, or rangeland.

[19] UNEP 1996 (see No.1 above).

Table 6: Estimated costs of direct anti-desertification measures (US-$/ha)

Degree of Land Degradation	Irrigated Lands	Rainfed Croplands	Rangelands
Slight to none	100 - 300	50 - 150	5 - 15
Moderate	500 - 1,500	100 - 300	10 - 30
Severe	2,000 - 4,000	500 - 1,500	40 - 60
Very severe	3,000 - 4,000	2,000 - 4,000	3 - 7

Source: UNEP, Status of Desertification, Financing the Plan of Action to Combat Desertification, Part IV, 1996.

Taking into account the above costs and the modified assessment of desertification in the MENA region (Table 5), the calculations yield the costs of rehabilitation in billions of US-$ (Table 7). The estimated costs are about US-$-8 billion per year, or US-$-160 billion for a 20-year program of anti-desertification measures in the region. Since the majority of MENA countries are poor, external assistance will be needed to finance such a program.

Table 7: Income foregone due to land degradation in the MENA region

Land Use	Total Area Desertified (1000's of ha)	Income Foregone due to Desertification (millions of US$, 1990)	Income Foregone if Land is not Rehabilitated*	
			Area to be Rehabilitated*	Costs of Rehabilitation (millions of US$)
Irrigated land	0	0	0	0
Rainfed cropland	21755	827	15229	4074
Rangeland	165317	1157	82659	3871
Total	187072	1984	97888	7945

Source: Computed from a) UNEP Desertification Report, Part IV, 1996 and b) UNEP/Dregne, 1992.
* 70% of desertified rainfed cropland, 50% of desertified rangeland.

3.6 Monitoring Indicators of Desertification Processes by means of Satellite Systems

Efforts to monitor desertification have always been subject to the criticism as there is a big discrepancy between the time frame of human monitoring activities and the time frame of desertification processes. What we have to study is not the changes that take place in a single year, but the changes that occur during a long time-series. Due to the lack of data and information on the real magnitude of desertification and its changes over time, it has been expedient to carry out these studies with the aid of satellites in view of their multispectral properties, which enable them to use thermal imaging techniques to represent vegetational cover.

3.6.1 Resolution of Existing Satellites

The first satellite to be launched successfully was the Soviet SPUTNIK, which went into orbit in 1957. Today, almost 10,000 satellites are being used to serve the earth and/or study the environment. The spatial resolution of satellites ranges from high-resolutions capable of imaging objects only five meters in size to low resolutions covering tens of kilometers[20]. The temporal resolution ranges between geo-stationary satellites and those that cover a certain strip of area every 10-16 days. The spectral resolution ranges between long-wave infrared (IR) and ultrashort-wave (UV).

3.6.2 Advantages of Satellites for Data Collection

In regard to the collection of environmental data, satellite remote sensing systems have the advantages that they can provide both regional and global data, use their unique sensing capabilities to monitor changes ranging in duration from half an hour to several weeks, and process the data collected for the purposes of comparison.[21].

3.6.3 The Most Well-Known Satellites

The most well-known satellites are: (a) the LANDSAT-TM series, which incorporate a thematic mapper (TM) and multi-spectral scanner (MS), and work at scales from 1:50,000 to 1:1,000,000, (b) the weather satellite METEOSAT, and (c) NOAA satellites, which provide an overall views of the earth through images made in the red (-R) and near-infrared (NIR) ranges, i.e. in the range of thermal radiation. In 1985, the FAO of the United Nations commissioned the establishment of a Global Information and Early Warning System (GIEWS) for natural disasters such as droughts, floods and earthquakes, and later formed FAO's Rome-based Remote Sensing Unit (FAO RSU).

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[20] CIESIN, The Importance of Satellite Remote Sensing for Global Change Research, 1996.
[21] CIESIN, The Use of Satellite Remote Sensing, 1996.

3.7 Using NOAA Satellites to Monitor Desertification in the MENA Region

Geographic information systems (GIS) are interesting tools for interdisciplinary agricultural modeling. Nevertheless, the use of a GIS usually involves a number of difficulties, including [22]: (a) the availability of data, (b) the availability of hardware and software competence, (c) statement accuracy and examination, and (d) the availability of an interdisciplinary work team. The validity of the results of desertification monitoring in this part of the study is subject to the above-mentioned difficulties.

The key element in controlling soil erosion in the MENA countries is vegetation cover. This study used thermal images generated by satellite remote sensing systems over a certain period of time to represent the vegetation cover in the MENA countries. Hielkema[23]considered the application of scales of up to 1:50,000 to be acceptable. Below this scale, e.g. 1:10,000 or at the farm level, satellite remote sensing would no longer be practicable. This is why the study used NOAA -systems to monitor vegetation as an indicator of desertification processes in the MENA region. Because the NOAA AVHRR satellite was established in 1982, the study is limited to coverage in the period from 1982 to 1997.

Since each satellite-generated image consists of a very large number of individual digitized dots, the data were processed by computer and the “Normalized Difference Vegetation Index” (NDVI) was computed. NDVI is a measure of the amount and vigor of the vegetation on the surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. The NDVI is derived from data collected by the National Oceanic and Atmospheric Administration (NOAA) satellites, and processed by the department of Global Inventory Monitoring and Modeling Studies (GIMMS) at the National Aeronautics and Space Administration (NASA). The NOAA-AVHRR sensor collects data at 1.1 km resolution at the satellite sub-point. The NDVI was calculated for both the entire MENA region and for each of the 17 countries of the region for the 16-year period from, 1982 to 1997. This was done in order to investigate vegetational development by year and by country (see examples of obtained vegetation maps).

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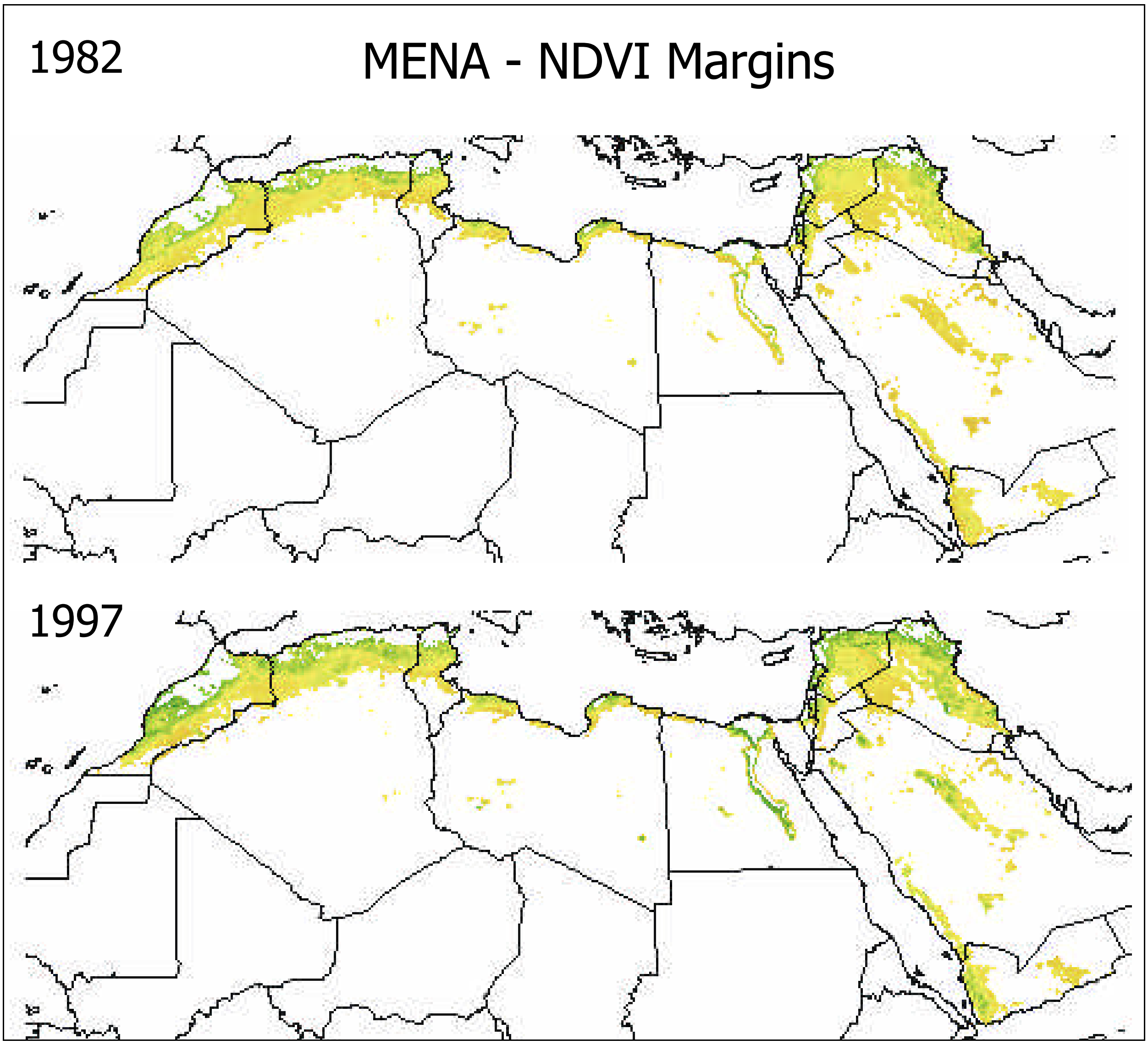
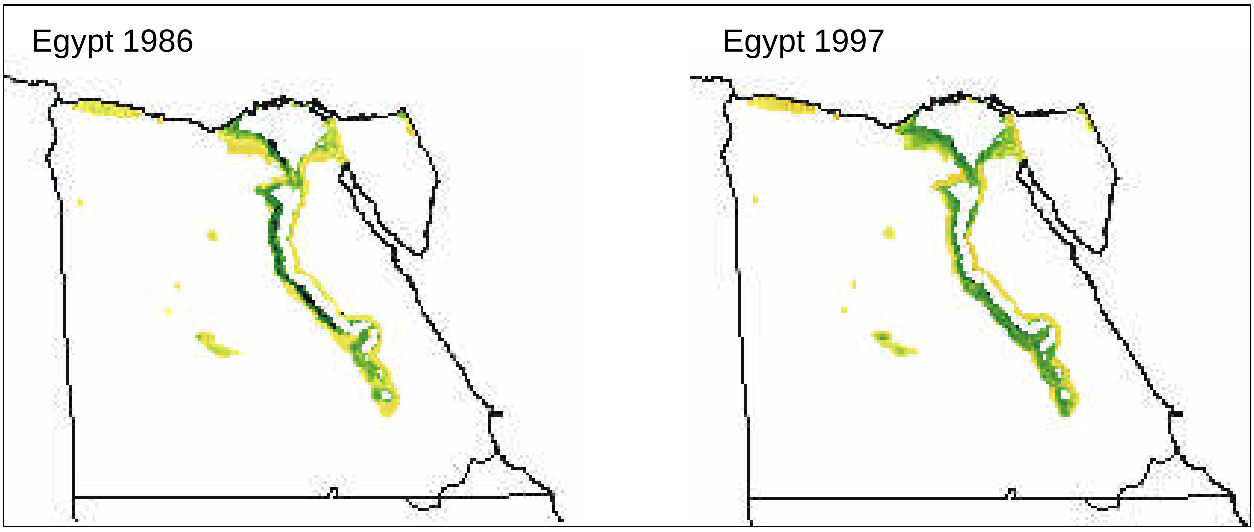
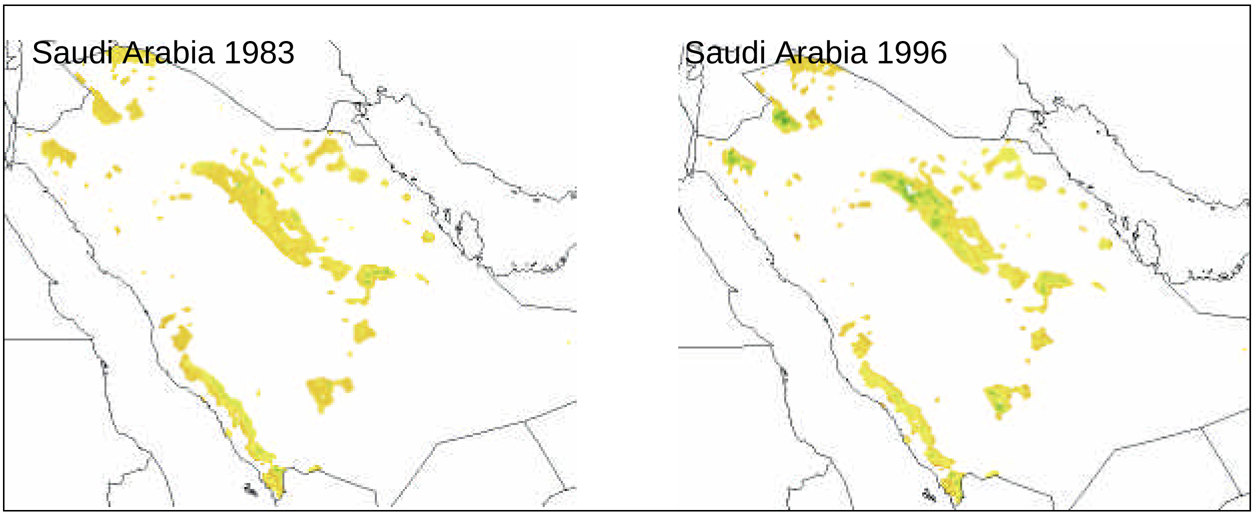
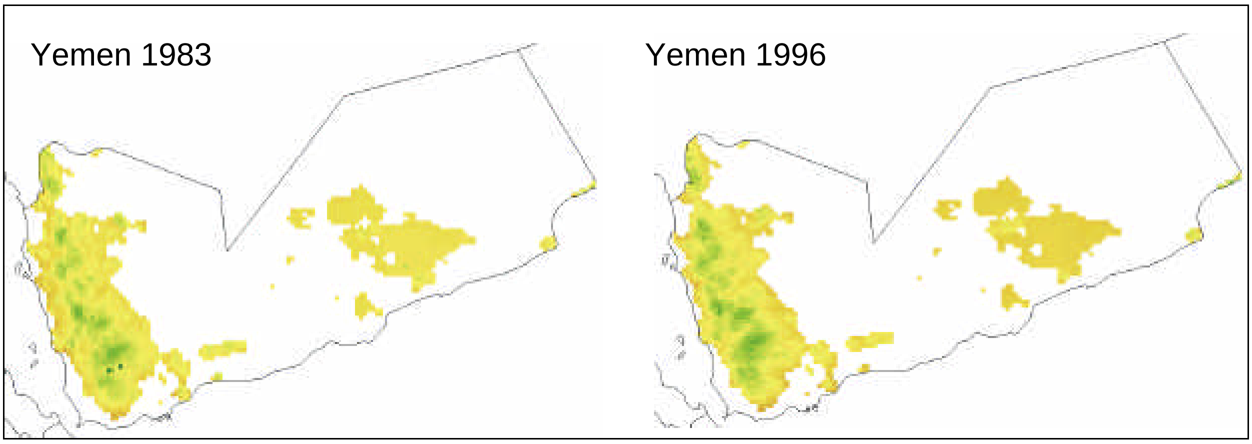
[22] Bill, R.U.D. “Fritsch, Grundlagen der Geo-Informationssysteme”, Band 1: Hardware, Software und Daten, Karlsruhe, 1994.
[23] FAO, Satellite Remote Sensing Specialist, R.S.C., Rome, Italy.


1982
MENA - NDVI Margins
1997


Egypt 1986
Egypt 1997


Saudi Arabia 1983
Saudi Arabia 1996


Yemen 1983
Yemen 1996

This study employed the following sets of satellite data:

- NOAA scene from 15 June 1997 (beginning of the dry season) for the generation of country-specific and overall MENA vegetation maps, that provide information on the density and distribution of vegetation; and
- NOAA scene from 26 February 1982 and 15 February 1997 (rainy season) to provide information on vegetation dynamics and land-degradation processes

Findings

The study compares the positions of the edges of deserts in the MENA region at two different times. The first time, the edges were plotted on a vegetation map from the year 1982. The second time, the edges were plotted on satellite images of vegetational cover from the year 1997. Comparison indicated a regeneration of the vegetational cover. The satellite images of the MENA region show no alarming damage to vegetation. Areas with extensive vegetation were bright or brightened on the satellite image. Although a drought occurred between 1982 and 1997 and the amount of rainfall was below average, the edges of the deserts had not shifted in 17 years, and some desert areas had even become greener. On the contrary, the study estimates that the vegetational boundary has shifted into the deserts in most of the MENA countries (see the NOAA satellite maps of the overall MENA region, and consider Egypt as example in North Africa, Yemen and Saudi Arabia as example of the Asian part of the MENA)[24].

Examination of the satellite images revealed no evidence substantiating a trend towards desertification in the region. In some places, regeneration of the vegetation could hardly be expected, given the continual destruction of woody plants that now occurs as a result of high population pressure. It is to be observed, however, that even the destruction of the shrub vegetation may have had a positive aspect for the region, namely that it may have promoted the growth of grasses. In fact, the satellite images document the presence of more greenery in the desert, but do not provide any precise indication of the nature or quality of the vegetation.

Land degradation may have occurred, but there has been no change to more desert-like (less vegetated) conditions. Of course, some small areas have suffered from one or more types of land degradation, but only for a very short time because the soil’s ability to regenerate itself has enabled the region to show a net increase in vegetational cover over last 17 years. In arid and semi-arid areas, the climate does in fact fluctuate wildly from year to year and from decade to decade. As a consequence of this, there is also marked fluctuation in the condition of natural and cultivated vegetation. One common source of confusion is when such fluctuation is attributed to “desertification”.

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[24] The NOAA has generated 36 satellite maps of the MENA countries that show changes in the distribution of vegetational cover between 1982 and 1997. These maps and calculations of NDVI s are available in the Center for Development Research (ZEF) at Bonn University.

Indeed, there are some indicators of land-degradation processes in the region, but it has demonstrated remarkable regenerative ability. Trails in Syria, Jordan, Tunisia, Libya and the Sudan have clearly demonstrated that tremendous improvement in the rangelands can be attained in only a few years following the introduction of proper stocking or deferred rotational grazing[25].

The destruction of vegetation has always proceeded from regions under human influence in response to the need for agricultural areas, roads, watering places, firewood, etc. For the region as a whole, however, it may be said that human influences have been positive and tended to increase vegetational cover in coastal areas and near rivers, where most of the population is concentrated. The MENA region's population growth of 3.3 percent annually has compelled people to try to utilize previously unused lands, where water is relatively available, in order to meet increasing demand for food.

Human efforts involving the use of biotechnology, including genetic engineering and the nitrogen-fixing ability of leguminous plants, offer considerable promise of narrowing the differences in yield between farmers and extension stations, without degrading the natural resource base. Human efforts have led to increasing time trends of grain yield, areas harvested and production of grain in most of the MENA countries.

Nevertheless, as in all satellite studies, the observed increase in the region's vegetational cover in no way denies the occurrence of other types of land degradation and provides no measure of land productivity. To gain some indications of the magnitude of other land-degradation problems in the region, other information relating to vegetation was consulted. This information include the amount of rainfall, crop yields, soil organic matter, use of fertilizers, and the number of animal grazing in each country over the same period of time.

Unfortunately, there is no information relating specifically to the desert areas of the MENA region that could be compared with information on the non-desert areas in each country. However, the results shown in Table 7 in the annex indicate that grain yields have increased in most of the MENA countries between 1982 and 1997. Thus, the increase in vegetational cover and increase in cultivated areas and grain yield, considered in conjunction with the reduced use of fertilizers, show that the region has not suffered significantly from the diminution or destruction of the biological potential of the land during the years 1982 through 1997.

This result agrees with the conclusions reached by FAO studies (see FAO, Food for All Report, 1997) that the MENA region is to be classified as mainly productive crop, pasture and forest land, and that desertification in the region is mostly moderate.

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[25] Arrar, A., in German Foundation for International Development (DSE), FAO, GTZ, UNESCWA, Resource Conservation and Desertification Control in the Near East, Report of the International Training Course, Germany and Kingdom of Jordan, 1989.

4 Using Water Harvesting Techniques to Control Desertification in the MENA Region

4.1 The History of Water Harvesting

The first water harvesting system in history was build in the MENA region. Researchers have found signs of early water harvesting structures believed to have been constructed over 9000 years ago in the Edom mountains in southern Jordan. One of the earliest documented complete water harvesting systems is located in the Negev Desert of Israel. It is believed to have been built about 4000 years ago[26]. Remnants of other installations were also discovered in Iraq and on the Arabian Peninsula, along the routes used at the time by caravans. The water harvesting installations consisted mainly of means to collect rainwater and divert it into natural and/or artificial ponds and reservoirs[27].

In Yemen, ruins of dams and reservoirs as well as the unique, spectacular mountain terraces, confirm the long history of water harvesting. The great historical Marib dam and its collapse are mentioned in the Holy Koran. Recent archaeological excavations (German Team, 1982 and 1984) discovered ruins of irrigation structures around Marib city dating from the middle of the third millennium BC (some 4000 years ago)[28].

Water harvesting installations dating from 2500 to 1800 BC have been discovered Palestine. They consisted mainly of cisterns with catchments areas cleared of gravel and smoothed to increase runoff. In the same region, during the Byzantine era, “the system of runoff farming encompassed practically all of the usable land in the northern Negev highlands.”[29]

In North Africa, rainwater collection and storage are known to have been practiced during the 11th and 12th centuries. In Morocco alone, it was estimated in 1990 that there are over 360,000 cisterns throughout the country that still supply domestic water to 10% of the population.

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[26] Gary, W. Frasier, Water Harvesting/ Runoff Farming Systems for Agricultural Production; in the FAO Proceedings of the Expert Consultation about “Water Harvesting for Improved Agricultural Production”, Water Report 3, Rome, 1994.

[27] M. Bazza, Operation and Management of Water Harvesting Techniques; in the FAO Proceedings of the Expert Consultation about “Water Harvesting for Improved Agricultural Production”, Water Report 3, Rome, 1994.

[28] Abdulrahman, M. Bamatraf, “Water Harvesting and Conservation Systems in Yemen”; in the FAO Proceedings of the Expert Consultation about “Water Harvesting for Improved Agricultural Production”, Water Report 3, Rome, 1994.

[29] Hillel, D., Negev, Land, Water, and Life in a Desert Environment, Praeger Publishers Division, 1982.

In Egypt, some water harvesting structures built in the Roman era have been, cleaned and/or smoothed and put back into use. At present, all the countries in the MENA region, practice one or more water harvesting techniques intensively in order to collect and store rainwater for use in meeting plant-cultivation, human and animal needs.

Awareness of the role of water harvesting (WH) in improving crop production was raised throughout the world in the 1970s and 1980s, when widespread droughts in Africa threatened agricultural production.

4.2 What is Water Harvesting?

In its broadest sense, water harvesting may be defined as the “collection of runoff for its productive use.”[30] Runoff may be harvested from roofs and ground surfaces, as well as from intermittent or ephemeral watercourses. Productive uses include provision of domestic and stock water, concentration of runoff for crops, fodder and tree production and, less frequently, water supply for fish and duck ponds.

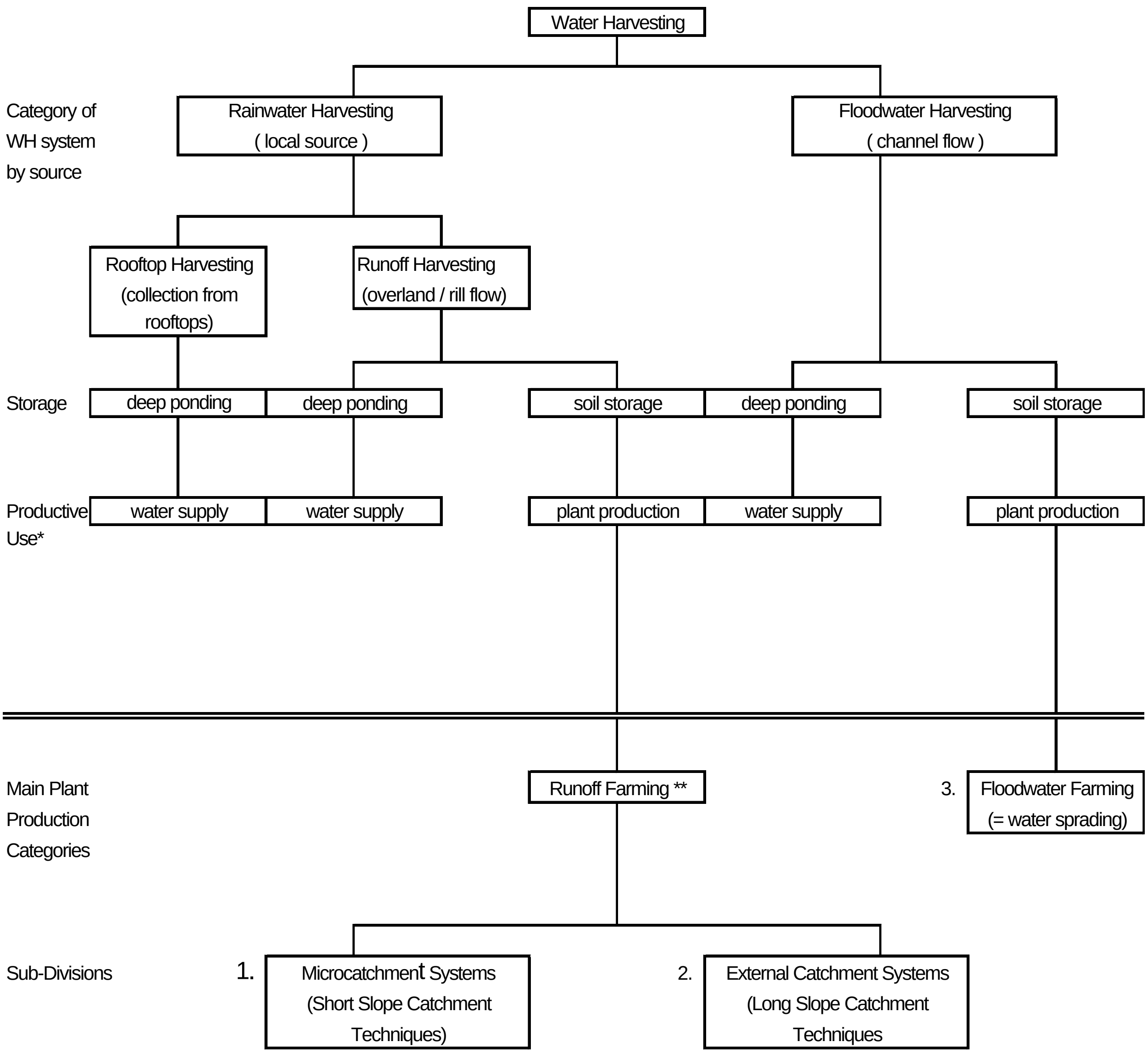
The techniques utilized for collecting, storing and using rain and flood waters are very diverse. There are consequently a dozen different definitions and classification of water harvesting techniques. The terminology of water-harvesting used at the regional and international levels has not yet been standardized.

In the next section, water harvesting is considered as a management technique for collecting, storing, and distributing rainwater for any productive use. In general, water harvesting can make water available in regions where other sources are too distant or too costly, making water harvesting able for supplying water for small villages, households, livestock, and agriculture.

The most practical classification of the various water harvesting techniques and their characteristics and uses has been established by the World Bank within the context of the “sub-Saharan Water Harvesting Study” in 1986- 1989 (Figure 1).

[30] Klaus Siegert, in the FAO Proceedings of the Expert Consultation about “Water Harvesting for Improved Agricultural Production”, Water Report 3, Rome, 1994.

Figure 1: Classification of water harvesting techniques



Notes:

* Water supply systems (i. e. ponded water) used for a variety of purposes, mainly domestic and stock water but also some supplementary irrigation.

** The term "farming" (as in "Runoff Farming") is used in its broadest sense - to include trees, agroforestry, rangeland rehabilitation, etc.

*** Deep ponding often also referred to as long term storage includes dams, reservoirs and all kind of tanks.

Source:
Siegert, K.: Introduction to water harvesting: some basic principles for planning, design and monitoring, in: The FAO Proceedings of the Export Consultation about "Water Harvesting for Improved Agricultural production", Water Report No. 3, Rome, 1994

4.3 Rainwater Harvesting Techniques Used in the MENA Region

Table 8: Overview of the main water harvesting techniques (WHT) used in the MENA region

Water Source	Objectives	Water Harvesting Technique	Country
Rainfall	- To increase rainfall effectiveness - To conserve water (and soil)	Terraces Terraces Contour-ridge terracing Dams	Yemen, Jordan Yemen, Tunisia, Jordan Libya, Syria, Tunisia, Jordan Egypt, Libya, Tunisia, Jordan
Local runoff	- To collect water - To store harvested water (also used for domestic supply)	Micro-catchment Cisterns	Yemen; Egypt, Libya, Syria, Jordan, Morocco Yemen, Egypt, Libya, Morocco
Wadi flow (flood and base flow)	- To divert water for irrigation - To protect land against floods (soil erosion control)	Earth dykes (spate irrigation and small-head pumps & earth canals) Wadi-bank enforcement	Yemen, Egypt, Libya, Tunisia, Jordan Yemen, Libya,
Spring water	- To deliver water to participants within water rights limits - To store limited quantities of water for short periods (also used for domestic supply)	Earth canals Cisterns	Yemen Yemen, Egypt, Libya, Morocco
Ground water	- To abstract water from shallow aquifers (also used for domestic supply) - To exploit groundwater stored in the coastal sand dunes	Shallow dug wells and pits Galleries	Yemen, Egypt, Libya, Tunisia, Jordan, Morocco Egypt

Source: Developed according to: Aleryani, M. L., and Bamatraf, A. M., Water Resources in Kuhlan-Affar/Sharis Districts, Annex C; in Final Report "“Dryland Resource Management in the Northern Highlands of Yemen", AREA/FAO/ICARDA Joint Project, 1993.

The productivity of land in the MENA region is determined to a large extent by the total amount and seasonal incidence of rainfall. Rainfall is generally meager (less than 300 mm per year), unpredictable and widely fluctuating. Most of the MENA countries are classified as water-scarce countries. The natural aridity of the MENA region is also a major constraint on productivity, and very little can be done to change it. However, rainwater can be managed in that it can be collected, stored, distributed, and more efficiently utilized to meet peopl's needs without actually having a greater amount of water available and without undesirable side-effects, such as desertification, occurring. This is called rainwater harvesting and is the key to controlling desertification, rehabilitating land and increasing productivity in the region. The main rainwater harvesting techniques used in the MENA region are summarized in Table 8.

In summary, most of the MENA countries use different local techniques to manage rainfall by improving the soil cover and thus catching rain where it falls and aiding infiltration, to increase soil moisture and increase organic activity in soils. People in the region consider water harvesting to be a mechanism for survival, with the result that water harvesting is considered to be an integrated part of agricultural production, of increasing the production of fruit trees, grasses and rangeland, of controlling soil erosion, and of conserving soil moisture when coupled with appropriate agricultural practices.

4.4 Problems and Constraints Hindering the Use of Water Harvesting for Agricultural Development

Since agriculture in most of the MENA countries is characterized by reduced water availability[31] and growing demand for food and thus for higher agricultural productivity, MENA countries have no option but to improve the efficiency of water use in agriculture. This must include efficient management of rainwater through utilization of effective water harvesting techniques. Instead of allowing runoff to cause erosion, it must be harvested and utilized.

Governmental and non-governmental agencies, supported by local leaders of the beneficiaries, take the responsibility for the implementation of successful water harvesting systems. Governmental agencies of the Ministry of Agriculture and/or Land Reclamation, i.e. Soil and Water Conservation Departments, and development and construction divisions, are responsible for planning, administering and managing soil and water conservation activities in the MENA countries, including water harvesting techniques.

As mentioned above, traditional techniques of harvesting water are still being used in all the MENA countries. FAO experts of the soil and water conservation group believe that there is a need to improve the efficiency of traditional techniques. Unfortunately, the introduction of

[31] Nasr, Mamdouh, "Agriculture: The Biggest User of Water", paper presented to: Water-International Conference, Bonn, October 1998.

systems which have been tested under various climatic, soil, land-tenure and socio-economic conditions are usually not accepted by the target groups.

The most significant problems and constraints hindering the integration of water harvesting in the agricultural production of the MENA countries are[32]:

- Technology inadequate to the requirements of the country/ region/ area;
- Lack of acceptance, motivation and involvement among beneficiaries;
- Lack of adequate hydrological data and information for confident planning, design and implementation of water harvesting projects;
- Insufficient attention to social and economic aspects such as land tenure, unemployment, and return of water harvesting system;
- Lack of effective involvement of the national research centers and extension services;
- Inadequate institutional structures, beneficiary organizations (associations, cooperatives) and government training programs for farmers, pastoralists and extension staff;
- Absence of a long-term government policy.

4.5 Using Rainwater Harvesting to Combat Desertification in Egypt: A Case Study[33]

4.5.1 Introduction

Since Egypt sets an example for the entire MENA region, the aim of this case-study is to identify major demographic, technical, social and economic forces driving desertification.

Data for the study was collected according to a multi-method approach, e.g. questionnaires (reconnaissance, pre-test and socioeconomic survey), case studies, and interviews with private, governmental and donor agencies in the region. A stratified random sample of 280 farms was chosen. The stratum selected was one that used a water harvesting technique. This was relevant for the research objectives. Using available maps, the target area was divided into three types of sub-areas. The first type included areas of farming and water harvesting; the second includes towns, villages and rural clusters of more than 10 houses and the third contained small HH with animal activities.

[32] Most of these problems and constraints are also identified by the FAO Expert Consultation for the Near East, Cairo, 1993.

[33] A survey was conducted within the research activities of the National Agricultural Research program (NARP) under the supervision of the Ministry of Agriculture and Land Reclamation, Project No. I-12, funded by USAID. The author of the present study was the principal investigator of this project during the 1992-1994 period. The project title was: “The Technical, Social and Economic Aspects of Water Harvesting and Water Supply of Rainfed Desert Farming Systems.

The study focussed on the household, its income, employment, water harvesting techniques, and cropping patterns. This was done to investigate key factors contributing to the degradation of land and water resources in the region. These factors were grouped into three categories: technical, socioeconomic and institutional. The technical factors included drought conditions, unfavorable hydro-geologic conditions, inefficient water control and delivery techniques, and poor land-use planning.

The socioeconomic factors involved inefficient cropping and cultural practices, inequitable resource allocation due to inflexible water rights and inappropriate land tenure, fragmentation of land holdings, social influences and/or tribal conflicts, and increased population growth with its greater needs and pressures limiting resource sustainability in the region.

4.5.2 Importance of Water Harvesting

The facts that rainfall is very meager in such semi-arid regions and that one millimeter of harvested rainwater is equivalent to one liter of water per square meter, suggest the importance of water harvesting apart from the quantity of rainwater collected. The population benefiting from the harvesting of rainwater is estimated at 161,000 inhabitants, 59% of which raise sheep and goats and cultivate barley and fruit trees in wadis and depressions where water can be harvested and utilized. Water harvesting also plays a role in people's social life.

The whole issue of land management by Bedouin tribes has recently been of great importance. Degraded land around the tribal sites can be improved only if the communities themselves come to grips with land use management issues. One of the techniques that can be of assistance in rehabilitating degraded land is water harvesting[34].

4.5.3 Technical Description of Water Harvesting Systems

Most water harvesting systems adopted by farmers in the region consist of four main components; catchment area for collecting rainwater, a means of diverting runoff, a water storage installation, and appropriate means for using the water.

Water Catchment

The Bedouins are experienced in selecting the most appropriate water catchment areas for collecting rainwater. As would reasonably be expected, the area they select as a catchment does not permit the water to infiltrate into the soil, is cleared of all vegetation, shaped, and smoothed. Farmers decide the size of catchment area and storage tank on the basis of their personal experience in the past. This involves seasonal observation of the farm water budget, i.e. the

[34] Siegert, K, water resources engineer, Water Resources, Development and Management Services, Land and Water Development Division, FAO, Rome, 1994.

amount of water harvested versus the amount of water required. Since the objective is to reduce the chance that there will be periods of insufficient water, the catchment area and water storage installation are made at least large enough to ensure that there will be sufficient water during periods of little rain.

Water Storage Techniques

Because of the intermittent nature of precipitation runoff, water storage is an integral part of every water harvesting system. There are two main methods of storing rainwater in the region. The first method relies on storing runoff water in wadi channels behind earthen dams in areas where slopes are not greater than 2%, or behind stone dams in areas where slopes are 1- 5%. The aim of establishing such dams is to hold the water until it is needed by building great water basins that can be exploited for up to 4 months after the end of rainfall season in March. In this type of water harvesting, the cultivated soil is the water storage container. This is called a direct-runoff-farming system. There are two basic types of runoff-farming systems: first, the direct water application system, where the runoff water is stored in the soil of the crop growing area during the precipitation, and second, the supplemental water system, where the collected water is stored offsite in some reservoirs and later used to irrigate a certain crop area.

The second method of rainfall storage used in the region relies on the building of earthen reservoirs in wadi depressions. The Bedouins in the region use two different kinds of earthen reservoirs. The first are lined reservoirs build according to engineering principals and utilizing materials from outside the region, e.g. concrete, or iron. These kinds of reservoirs are extremely expensive and are usually built by the local administration of Matrouh governorate.

The second kind of reservoirs are what Bedouins call “Nashou”. These are established cisterns under the surface of a plateau. Because of the topographical soil conditions, the selection of a suitable place for building such a cistern is of great importance. The Bedouins have sufficient experience in this.

Material and labor are of primary concern when selecting a water-harvesting farming scheme. Not all catchment basin designs require the same labor skills or the same type of maintenance. Maintenance on small-scale water harvesting schemes can require 1 to 2 man/days about 4 times per year. In order to compact the soil in catchment basins, weed growth should be eliminated and soil erosion prevented.

4.5.4 Socio-economic Indicators of Successful Rainwater Harvesting in Egypt

This part of the study describes the socioeconomic indicators of agricultural development relating to rainwater harvesting techniques in the study area. These indicators include the land tenure system, land management, cropping patterns, farm income and sources of farm revenues, the gross margins of selected agricultural products and livestock, animal nutrition management, and the rate of profitability of farm production.

Land Tenure and Management

The lack of title to land is one important factor affecting the improvement of water harvesting techniques in the area because the lack of tenure means that people are reluctant to invest in new water harvesting structures or in land which they do not formally own.

Land management has recently been acknowledged to be extremely important, particularly in such a semi-arid area. Because of the shortage of water, land holding is characterized by small-scale farm sizes. Of course, the level of education and social status of farm managers play an important role in the use of land and water resources. The better educated farmers are, the more efficient is their use of farm resources.

Water Harvesting in the Area

Most of the water harvesting systems used by households in the area were developed and utilized as single-family enterprise. Large communal systems are seldom to be found due to their high installation costs and demanding requirement for group commitment, not only for the construction of the system, but also for its maintenance and operation. In combination systems, earthen dikes are usually used in addition to cisterns. Where water infiltration is a problem, due to soil degradation, earthen and stone dikes are effective particularly if combined with animal manure. Constructing earthen dikes is one of the methods of guiding runoff. The aim of this work is to use the soil for water storage up to the limit of its capacity, thus also supplying the water needs of plants rooted in the immediate area.

If the water collected represents the means of survival rather than merely an opportunity to generate income, people have a different attitude about it. When farmers harvest water for their own survival, they are ready to spend more money and invest more labor in building cisterns since, in this case, the water has a different economic significance than water that is used as a means of increasing income.

The spread of knowledge regarding water harvesting techniques may facilitate successful implementation of programs designed to improve water-harvesting infrastructures with a view to controlling land degradation in the region. However, farmers' current knowledge regarding water harvesting techniques is inadequate and out dated, with the result that much rainwater is lost (78%).

Livestock Production

For most Beduins, keeping livestock is not only a source of income, but a way of life. Farmers' prestige is closely correlated with the size of their herd. Farmers consider livestock almost like a bank, enlarging their herd when they have surplus money, and converting it to cash when they need money.

In spite of the relatively low, but positive gross margins per unit of labor and water returned by barley, farmers are encouraged to keep cultivating it in order to cover increased demand for grain resulting from increased herd sizes. Cultivating land with barley reduces the threat of its degradation because plowing opens the soil crust and raises the rate of infiltration. At the same time, the increased profitability of orchard enterprises enables farmers to invest more in water harvesting structures and thus indirectly reduce the threat of land degradation[35].

Costs of rehabilitating land

A recent study[36] estimated the investments required to upgrade the arable land in the study area at $ 1485/ ha, assuming that the work was performed by private contractors. Governmental overheads and supervision costs were not considered. The most important activities proposed to upgrade this area were: landscaping (terracing, leveling, etc.), water provision (dikes, dams, cisterns, etc.), groundwater wells including pumping facilities, and feeder roads. The implementation of these improvements might be feasible within a period of five years.

Net farm income

A farm income of US$ 5000, believed to be the minimum income required for an acceptable standard of living for a family of average size (ten members), has not been achieved. This is equivalent to a $ 500 per capita per year, which is less than Egypt's national average of $ 650 (1995). The annual income of most farms (75% of the farms surveyed) at 1994 prices, however, ranges between $ 630 and $2380, which is much less than 50% of the income expected (GTZ/QRDP, 1993).

[35] This result was confirmed in a recent study in the same area conducted by Qaim Martin, Modernization of Farming Systems in the Northwest Coastal Zone of Egypt, Qasr Rural Development Project Area, M.Sc. thesis, Kiel University, 1996.

[36] "Estimation of Development Costs for the Area of Qasr Rural Development Project (QRDP) at Marsa Matrouh", Internal Report of GTZ/ QRDP, Marsa Matrouh, Egypt, 1993.

4.5.5 General Conclusions of the Case Study

Of course, there are some indications of one or more types of land degradation here and there, i.e. overgrazing and/or soil erosion, but these processes are temporary, and the soil's ability to generate itself is very high, particularly in wet years. The overall development is positive, since the cultivated area in the region increased by 40% between 1980 and 1996. Thus, the ecological consequences of human activities remained relatively insignificant or were concentrated within a limited area, because the population densities of both men and cattle are sufficiently low in areas threatened by desertification.

Traditional "water harvesting" techniques can achieve significant improvements both in agricultural production and environmental rehabilitation. These techniques have contributed to the rapid restoration of vegetational cover and helped to reverse erosion in degraded areas in the north-west coastal areas of Egypt.

Intensified establishment of water and soil conservation facilities has led to desertification control and desert reclamation activities and thus to an increase of 15% in newly cultivated areas at surveyed farms. Effective coordination of governmental, non-governmental, and donors efforts is required to ensure the necessary investments, research, and extension work.

Farmers have increasing awareness of the problems entailed in overgrazing, of the need to strengthen the vegetational cover, and to intensify work against soil erosion. Windbreaks and plantations of fruit trees have increased by 30% among the surveyed farmers.

The trend toward increasing crop yields in conjunction with diminished use of chemical fertilizers, indicates the success of human efforts to sustain productivity.

However, since there is still a big need for sustainable development in the study area, the governmental agencies working in the area, supported by foreign donors, should establish a database on land degradation trends, causes, results, and implications, and develop clearly defined policy alternatives for reducing resource degradation. Soil surveys, and satellites maps for classifying land in terms of soil types and erosion, vegetational cover, water availability, and climatic information represent a comprehensive instrument for establishing this database.

4.5.6 Governmental and Non-Governmental Actions to Combat Desertification

Although the Bedouins have traditionally been a nomadic population, the government's determined policy of encouraging their settlement, has had the effect that only a negligible proportion of them are now entirely nomadic (with no fixed place of residence to which they return for some portion of every year).

A relatively large number of international projects are being implemented in the northwest coastal region of Egypt. This reflects the special interest of both national and international organizations to develop this region. With assistance from the World Food Programme (1979), GTZ/ QRDP (1988), FAO (1965), ILO (1984), USAID (1979) and from the Egyptian government, the majority of the households in this region now have a permanent dwelling. Only a minority of rural households still rely on tents as their sole source of shelter. No nomads are found close to the coastline, but in the southern extremities of the region there are still nomads who keep moving with their animal herds in search of seasonal pasture.

The beneficiaries show great interest in both national and international projects and this has resulted in the continuation of the projects through several phases. At the same time, the interventions made are replicable and are demonstrated by the significant social and economic benefits to which these projects contributed[37]: settlement of the nomadic Bedouins, increases in crop and livestock production, creation of stable society with improved living standards, improved water harvesting structures, and improved conditions for women in productive activities.

Table 9 shows the contribution of the WFP in the area of water harvesting compared with the contribution by the Egyptian government during the 1980-1991. The implemented water storage facilities and water harvesting techniques are aimed at maximizing the use of water resources available in the area. The implementation of WFP's-activities through the government authorities using traditional techniques on a self-help basis ensures the sustainability of activities and helps the local Bedouins to settle and to stabilize their income.

Table 9: Implementation of water harvesting structures, 1980- 1991

Type	Volume (m^3)	WFP No.	Volume (m^3)	Government No.
Clearing of old Roman cisterns	2 534	411 400	3 011	1 394 107
Excavation of new cisterns	4 285	903 177	3 104	696 592
Stone dikes	9 047	750 299	-	-
Cemented dikes	321	32 178	899	127 999

Source: Taher, A., Agricultural Development in the Northwest Zones of Egypt, Soils and Water Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Egypt, 1993.

[37] Taher, A., Agricultural Development in the Northwest Zones of Egypt, Soils and Water Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Egypt, 1993.

5 Policy Implications

5.1 Improving the Data Base

"On the basis of experience in implementing the Plan of Action to Combat Desertification (PACD) during 1978-1991, it could be stated that the PACD is dealing with a problem that cannot be solved once and for all."[38] It would therefore be unrealistic to fix a date by which the PACD should be fully implemented. "Not surprisingly, the financial provisions proved to be the hardest part of the Convention to negotiate."[39] The Secretariat for the Convention to Combat Desertification concentrates on mobilising adequate financial resources for the PACD.

Most actions dealing with desertification, particularly in the MENA region, are monitoring actions and are therefore concerned with evaluating the damage and/ loss attributable to desertification. The UNEP estimates that worldwide costs for corrective and rehabilitative measures on drylands affected by desertification total US$ 8.6 - 18.2 billion per year[40]. To date, however, the program's calls for funding have fallen upon deaf ears. Moreover, it is not known how much individual countries are spending or how much multilateral funding for implementing the PACD is being provided by donor countries and international agencies, either within or outside the United Nations' system. Only scattered information from a few donors and agencies is available, presenting no clear global picture[41]

5.2 Research into Economic Alternatives and Options

Assessments of exactly how much land turns into desert each year hinge largely on definitions. It may be that spending money on better use of the desert in the MENA region is much wiser than spending it on measures to combat desertification. This includes that spending on basic research on better management of desert land and water resources, may be more efficient, too, namely the cultivation of the desert. Investments in improving water-harvesting facilities and systems in the region have proved to be economically viable and socially acceptable (as evidenced by a case study in Egypt). The funds can be used to intervene in the life of individual villages to bring soil degradation to a halt.

[38] UNEP, Status of Desertification and Implementation of the United Nations Plan of Action to Combat Desertification, Executive Summary, 1996.
[39] The Secretariat for the Convention to Combat Desertification, Down to Earth, 1998.
[40] UNEP 1996 (see No. 38 above).
[41] UNEP 1996 (see No. 38 above).

It is to be hoped that current funding of anti-desertification measures will shift over the course of time from desertification control and rehabilitation to sustainable desert cultivation with appropriate use of available water resources. Many investments made to cultivate the desert by increasing the amount of rainwater harvested, can be effective measures for combatting desertification.

The assessment of the current status of land degradation throughout the world shows that there is a lack of hard, precise data that allows conclusions to be drawn regarding the extent and rate of desertification in various parts of the world. This result offers some relief from the alarm caused by currently existing estimates and calls for more precise studies based on surveys in combination with satellite remote sensing systems and aimed at determining the magnitude of the problem throughout the world and the extent to which man is responsible.

There are no reliably accurate estimates of the total economic loss resulting from desertification in the various parts of the world, or particularly in the MENA region. Economic losses directly attributable to desertification can be calculated only at the sites where the desertification occurs. To assess the losses in productive capacity resulting from land degradation in various land-use systems, it would be necessary to conduct a series of economic studies. This could be done based on the given conditions and existing experience of several MENA countries. Cross-country comparison, however, provides an idea of the differences between various land-use systems, and thus contributes to the investigation of the impact and causes of desertification processes and the development of possible countermeasures.

At present, there is not even a rough estimate available of the off-site and other indirect economic losses resulting from desertification. To shed light on this topic, there is a need for more extensive country-specific research investigating the differences between various socio-economic situations and avoiding generalization in this respect.

5.3 On Practical Issues of Desert Land Use

On the practical side of programs and projects of desert land and water resource utilization, a lot of experience has been accumulated over time. Much of that knowledge resides in local communities. Even though improvements in land and water use under desert conditions are very site-specific, the following- guidelines can frequently be proposed:

i. that target groups be integrated and actively participate in any water-harvesting projects implemented;
ii. that only simple, small-scale projects be implemented;
iii. that the small-scale projects be consolidated into regional and national plans of action;
iv. that the decision-making processes of the national support services be decentralized to the sites concerned and
v. that the role of international organizations be largely an advisory one, and less so an implementory one in national plans of actions, as this should properly be the task of decentralized, national organizations.

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Annex

Table 1: Estimated Global Land Use of Drylands, by Continent (in 1000 hectares)

Continent	Irrigated Area	Rainfed Area	Rangeland Area	Hyperarid Area	Total Dryland Area
Africa	10424	79822	1342345	705356	2137947
Asia	92021	218174	1571240	187840	2069275
Australia & New Zealand	1870	42120	657223	0	701213
Europe	11898	22106	111570	0	145574
North America	20867	74169	483141	3066	581243
South America	8415	21346	390901	19837	440499
World's total	145495	457737	4556420	916099	6075751

Source: Calculated from UNEP (1996) and Dregne, H. E., and N-T. Chou., Global Desertification Dimensions and Costs. In Degradation and Restoration of Arid Lands. Lubbock: Texas Tech. University , 1992.

Table 2: Estimated Global Desertification by Drylands, by Continent (in 1000 hectares)

Continent	Irrigated Land			Rainfed Crop Land			Range Land		
	Total	De-graded	% of De-grad'n	Total	De-graded	% of De-grad'n	Total	De-graded	% of De-grad'n
Africa	10424	1902	18%	79822	48863	61%	1342345	995080	74%
Asia	92021	31813	35%	218174	122284	56%	1571240	1187610	76%
Australia & New Zealand	1870	250	13%	42120	14320	34%	657223	361350	55%
Europe	11898	1905	16%	22106	11854	54%	111570	80517	72%
North America	20867	5860	28%	74169	11611	16%	483141	411154	85%
South America	8415	1417	17%	21346	6635	31%	390901	297754	76%
Total Dryland	145495	43147	30%	457737	215567	47%	4556420	3333465	73%

Source: Calculated from UNEP (1996) and Dregne, H. E., and N-T. Chou., Global Desertification imensions and Costs. In Degradation and Restoration of Arid Lands. Lubbock: Texas Tech. University , 1992.

Table 3: Estimated Land Use in the MENA Countries (in 1000 hectares)

Country	**Irrigated Area**	**Rainfed Area**	**Rangeland Area**	**Hyperarid Area**	**Total Dryland Area**
Algeria	338	6934	38120	190063	235455
Egypt	2486	10	2604	94900	100000
Libya	234	1659	17172	157655	176720
Morocco	525	7484	36693	1050	45752
Tunisia	215	4258	7968	3037	15478
Bahrain	1	0	50	0	51
Iraq	1750	1950	38395	0	42095
Israel	271	147	369	1246	2033
Jordan	43	375	6862	1820	9100
Kuwait	1	0	2306	0	2307
Lebanon	86	214	688	0	988
Oman	41	6	19642	7506	27195
Qatar	0	4	876	220	1100
Saudi Arabia	415	760	112345	126480	240000
Syria	652	4971	12945	0	18568
U.A. Emirates	5	0	1008	8197	9210
Yemen	309	1209	32590	1692	35800
Total MENA	7372	29981	330633	593866	961852

Source: Calculated from UNEP (1996) and Dregne, H. E., and N-T. Chou., Global Desertification Dimensions and costs In Degradation and Restoration of Arid Lands. Lubbock: Texas Tech. University , 1992.

Table 4: Estimated Desertified Irrigated Land in the MENA Countries (in 1000 hectares)

Country	Total Irrigated Area	Degree of Desertification				Total incl. Moderate	% of Desertified Area
		Slight	Moderate	Severe	Very Severe		
Algeria	338	288	40	10	0	50	15%
Egypt	2486	1735	700	50	1	751	30%
Libya	234	179	50	5	0	55	24%
Morocco	525	474	51	0	0	51	10%
Tunisia	215	145	60	10	0	70	33%
Bahrain	1	1	0	0	0	0	0%
Iraq	1750	500	750	300	200	1250	71%
Israel	271	230	31	10	0	41	15%
Jordan	43	30	10	3	0	13	30%
Kuwait	1	1	0	0	0	0	0%
Lebanon	86	80	6	0	0	6	7%
Oman	41	30	11	0	0	11	27%
Qatar	0	0	0	0	0	0	0%
Saudi Arabia	415	155	200	40	20	260	63%
Syria	652	542	70	30	10	110	17%
U.A. Emirates	5	3	2	0	0	2	40%
Yemen	309	259	40	10	0	50	16%
Total MENA	7372	4652	2021	468	231	2720	37%

Source: Calculated from UNEP (1996) and Dregne, H. E., and N-T. Chou., Global Desertification Dimensions and Costs. In Degradation and Restoration of Arid Lands. Lubbock: Texas Tech. University , 1992.

Table 5: Estimated Desertified Rainfed Cropland in the MENA Countries (in 1000 hectares)

Country	Total Rainfed Area	Degree of Desertification				Total incl. Moderate	% of Desertified Area
		Slight	Moderate	Severe	Very Severe		
Algeria	6934	484	5800	600	50	6450	93%
Egypt	10	9	1	0	0	1	10%
Libya	1659	1079	540	40	0	580	35%
Morocco	7484	2284	4900	270	30	5200	69%
Tunisia	4258	1318	2500	400	40	2940	69%
Iraq	1950	550	1150	230	20	1400	72%
Israel	147	47	35	63	2	100	68%
Jordan	375	165	155	54	1	210	56%
Lebanon	214	84	90	39	1	130	61%
Oman	6	3	2	1	0	3	50%
Qatar	4	3	1	0	0	1	25%
Saudi Arabia	760	300	420	38	2	460	61%
Syria	4971	1471	2840	650	10	3500	70%
Yemen	1209	429	700	73	7	780	65%
Total MENA	29981	8226	19134	2458	163	21755	73%

Source: Calculated from UNEP (1996) and Dregne, H. E., and N-T. Chou., Global Desertification Dimensions and Costs. In Degradation and Restoration of Arid Lands. Lubbock: Texas Tech. University , 1992.

Table 6: Estimated Desertified Rangeland in the MENA Countries (in 1000 hectares)

Country	Total Rangeland Area	Degree of Desertification				Total incl. Moderate	% of Desertified Area
		Slight	Moderate	Severe	Very Severe		
Algeria	38120	3820	9200	25000	100	34300	90%
Egypt	2604	504	300	1800	0	2100	81%
Libya	17172	3472	1700	11800	200	13700	80%
Morocco	36693	3693	3000	29900	100	33000	90%
Tunisia	7968	1168	1270	5500	30	6800	85%
Bahrain	50	40	10	0	0	10	
Iraq	38395	3895	7000	27250	250	34500	90%
Israel	369	39	80	230	20	330	89%
Jordan	6862	662	1150	5000	50	6200	90%
Kuwait	2306	346	1558	400	2	1960	
Lebanon	688	68	159	436	25	620	90%
Oman	19642	1942	5000	12650	50	17700	90%
Qatar	876	86	400	385	5	790	90%
Saudi Arabia	112345	22345	60000	29800	200	90000	80%
Syria	12945	1345	3000	8550	50	11600	90%
U.A. Emirates	1008	108	198	700	2	900	
Yemen	32590	6590	10000	15900	100	26000	80%
Total MENA	330633	50123	104025	175301	1184	280510	85%

Source: Calculated from UNEP (1996) and Dregne, H. E., and N-T. Chou., Global Desertification Dimensions and Costs. In Degradation and Restoration of Arid Lands. Lubbock: Texas Tech. University , 1992.

Table 7: Comparative Development of Yields (t/ha) of Grain in the MENA Countries, 1975- 1997 Part 1

Year	Egypt	Libya	Tunisia	Algeria	Morocco	Iraq	Israel	Jordan
1975	3,5	0,4	1,0	0,8	0,9	0,6	2,3	0,4
1976	3,3	0,4	0,8	0,7	1,1	0,9	1,9	0,5
1977	3,3	0,2	0,6	0,4	0,6	0,8	2,1	0,5
1978	3,3	0,4	0,8	0,6	1,1	0,6	1,9	0,4
1979	3,2	0,4	0,7	0,6	1,1	0,6	1,6	0,2
1980	3,1	0,5	1,0	0,7	1,1	0,7	2,6	1,0
1981	3,3	0,6	1,2	0,7	0,5	0,8	2,1	0,5
1982	3,5	0,8	1,3	0,6	1,3	0,8	1,6	0,5
1983	3,6	0,8	0,7	0,6	1,0	0,7	3,3	0,9
1984	3,7	0,7	0,8	0,6	1,1	1,0	1,5	0,8
1985	3,8	0,7	1,3	0,9	1,2	0,9	1,6	0,7
1986	3,8	0,9	0,9	0,8	1,7	0,8	1,9	0,7
1987	4,7	0,9	1,4	0,8	1,1	0,8	3,1	1,0
1988	4,8	0,8	0,8	0,6	1,7	0,9	2,4	1,1
1989	4,9	0,8	0,8	0,8	1,5	0,8	2,2	1,0
1990	5,2	1,2	1,3	0,6	1,3	1,0	3,2	1,4
1991	4,8	1,2	1,7	1,1	1,9	0,8	2,1	1,2
1992	5,3	1,1	1,7	1,0	0,7	0,6	2,9	1,5
1993	5,3	1,1	1,4	0,8	0,7	0,6	2,7	1,5
1994	5,0	1,0	1,1	0,8	1,8	0,7	1,3	1,6
1995	5,4	1,1	1,3	0,9	0,6	0,8	3,0	2,1
1996	5,6	1,1	1,6	1,3	1,8	0,9	2,3	1,1
1997	5,6	1,0	1,1	0,8	0,9	0,8	1,7	1,1
*Avg	4,3	0,8	1,1	0,8	1,2	0,8	2,2	0,9

* Average
Source: FAO Statistics, 1998.

Table 7: Comparative Development of Yields (t/ha) of Grain in the MENA Countries, 1975– 1997 Part 2

Year	Syria	Kuwait	Lebanon	Oman	Qatar	Saudi A.	Yemen	Emirates
1975	0,9		1,3	1,7	0,8	2,1	1,2	1,2
1976	1,1		1,1	1,7	0,9	1,3	1,2	1,5
1977	0,8		1,1	0,8	1,3	1,7	1,1	2,2
1978	1,1		1	0,5	2,2	2,0	0,8	2,4
1979	0,9		0,9	0,5	2,2	2,1	1,1	2,0
1980	1,5		2,3	0,5	2,4	2,1	1	2
1981	1,7		1,3	1,2	2,3	2,5	1,1	1,4
1982	1,3		1,3	3,8	3,2	2,8	1,1	1,6
1983	1,2		1,1	3,8	2,7	3,3	0,7	1,3
1984	1,0		1,2	3,8	2,7	3,5	0,8	1,2
1985	1,4	0,3	1,3	1,1	2,3	3,6	1,0	1,1
1986	1,8	0,3	1,5	1,1	2,4	4,0	1,3	0,8
1987	1,4	0,4	2,0	1,1	2,3	4,4	1,5	1,9
1988	1,9	0,3	2,0	1,5	2,3	4,5	1,7	2,2
1989	0,8	0,3	2,2	1,9	2,3	4,4	1,7	1,6
1990	1,5	0,3	2,0	2,4	2,3	4,6	1,6	2,3
1991	1,7	0,3	2,2	2,3	2,3	4,5	1,2	0,9
1992	2,2	0,3	2,3	2,3	2,3	4,5	1,6	1,9
1993	2,6	0,3	2,3	2,4	2,3	4,5	1,6	1,7
1994	2,4	0,4	2,2	2,4	2,3	4,5	1,7	1,2
1995	2,5	0,5	2,5	2,4	2,3	2,8	1,7	1,4
1996	2,5	0,4	2,5	2,4	2,3	4,4	1,4	1,8
1997	1,7	0,5	2,5	2,3	2,3	5,4	1,2	0,9
*Avg	1,6	0,2	1,7	1,9	2,2	3,5	1,3	1,6

* Average
Source: FAO Statistics, 1998.

Table 8: Livestock Density (head/ha) in the MENA Countries, 1997- 1994 Part 1

Years	Egypt	Algeria	Tunisia	Libya	Morocco	Bahrain
1975	0,03	0,33	7,36	0,49	1,13	4,05
1976	0,03	0,32	7,03	0,52	1,03	4,1
1977	0,03	0,35	7,14	0,43	1,02	4,14
1978	0,03	0,37	6,15	0,44	1,02	4,18
1979	0,03	0,41	5,00	0,54	0,96	5,27
1980	0,03	0,44	5,89	0,54	1,08	5,27
1981	0,04	0,52	5,52	0,44	1,01	5,27
1982	0,04	0,54	6,02	0,53	0,68	5,5
1983	0,05	0,54	6,19	0,51	0,84	5,5
1984	0,05	0,58	6,63	0,47	0,75	5,5
1985	0,05	0,58	7	0,48	0,84	6
1986	0,05	0,59	6,46	0,44	0,95	6,8
1987	0,06	0,60	6,86	0,41	1,05	7,63
1988	0,06	0,60	6,68	0,41	0,85	8,38
1989	0,06	0,63	6,73	0,45	0,91	8,83
1990	0,06	0,65	7,25	0,47	0,90	9,32
1991	0,06	0,63	7,60	0,47	0,85	9,2
1992	0,06	0,67	7,75	0,45	0,85	9,13
1993	0,07	0,69	8,53	0,43	0,75	8,95
1994	0,07	0,64	7,49	0,40	0,82	8,63

Source: Computed from FAO Statistics for Number of Animals (Sheep and Goats) and Areas of Rangelands, 1998.

Table 8: Livestock Density (head/ha) in the MENA Countries, 1997- 1994 Part 2

Years	Syria	Jordan	Israel	Iraq	Lebanon	Kuwait
1975	0,77	1,58	2,83	2,81	46	1,47
1976	0,88	1,20	2,89	2,85	40	1,60
1977	0,95	1,47	3,05	2,96	36	1,80
1978	0,99	1,58	3,25	2,95	50	2,64
1979	1,10	1,89	3,33	2,96	55,5	4,13
1980	1,23	1,65	3,19	3,27	59	3,91
1981	1,38	2,03	2,99	3,43	59	2,64
1982	1,51	2	3,11	3,14	58,45	1,84
1983	1,73	1,80	2,52	3,07	58	1,88
1984	1,65	1,74	2,84	2,83	60	2,57
1985	1,45	2,07	2,57	2,51	60,5	3,07
1986	1,53	1,73	2,57	2,61	60	1,86
1987	1,65	2,12	2,90	2,63	60,61	2,37
1988	1,79	2,26	3,30	2,64	60,54	2,34
1989	1,88	2,53	3,51	2,61	55,98	2,57
1990	1,97	2,60	3,38	2,50	53,33	2,02
1991	2,04	3,10	3,38	1,72	59,13	0,39
1992	1,94	3,10	3,25	1,64	53,23	0,59
1993	1,36	3,23	2,97	1,55	47,57	1,40
1994	1,48	3,36	3	1,45	44,13	1,88

Source: Computed from FAO Statistics for Number of Animals (Sheep and Goats) and Areas of Rangelands, 1998.

Table 8: Livestock Density (head/ha) in the MENA Countries, 1997- 1994 Part 3

Years	Saudi A.	Qatar	Oman	Yemen	Emirates
1975	0,05	1,59	0,35	0,35	1,75
1976	0,06	1,58	0,44	0,34	1,37
1977	0,06	1,55	0,54	0,35	1,73
1978	0,07	1,50	0,64	0,35	2,15
1979	0,07	2,11	0,68	0,35	2,23
1980	0,08	2,03	0,74	0,37	2,37
1981	0,07	1,88	0,77	0,38	2,48
1982	0,1	1,08	0,83	0,38	2,60
1983	0,11	1,22	0,84	0,39	2,84
1984	0,11	1,39	0,84	0,40	3,03
1985	0,10	2,80	0,9	0,40	3,25
1986	0,10	3,73	0,92	0,41	3,47
1987	0,1	4,16	0,93	0,41	3,72
1988	0,09	4,2	0,93	0,42	3,98
1989	0,08	4,32	0,94	0,43	4,26
1990	0,08	4,55	0,97	0,44	3,96
1991	0,09	4,48	0,87	0,42	3,90
1992	0,09	5,29	0,88	0,43	3,89
1993	0,09	6,16	0,88	0,44	3,88
1994	0,1	6,79	0,88	0,43	4,12

Source: Computed from FAO Statistics for Number of Animals (Sheep and Goats) and Areas of Rangelands, 1998.