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Environmental Security

Desertification in the Mediterranean Region

A Security Issue

Edited by
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José L. Rubio
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Springer

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Desertification in the Mediterranean Region.
A Security Issue

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Series C: Environmental Security –Vol. 3

Desertification in the Mediterranean Region. A Security Issue

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Participants of the NATO-CCMS and Science Committee Workshop in the Museum of Science Principe Felipe of the city of Art and Sciences of Valencia, Spain.
(Photography: Javier Yaya)

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FOREWORD

Desertification in the Mediterranean Region: a Security Issue

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Security issues related to desertification in the Mediterranean Region were the subject of a special NATO workshop held on 2-5 December 2003 at the Museum of Sciences Principe Felipe in Valencia, Spain.

This workshop was organized by the U.S. Environmental Protection Agency (Las Vegas, Nevada, USA), Centre for Desertification Research (Valencia, Spain), and the Desert Research Institute (Reno, Nevada, USA) on behalf of the NATO Science Committee and the NATO Committee on the Challenges of Modern Society (Public Diplomacy Division). Additionally, the European Society for Soil Conservation participated as a collaborating institution. Other participating institutions included the Spanish Ministry of Environment, Generalitat Valencia (Department of Territory and Housing), the Secretariat of the United Nations Convention to Combat Desertification and the City of Art & Sciences of Valencia which hosted the Meeting.

The Workshop focused on two basic concepts: *security* and *desertification* and their linkages. Since the end of the Cold War, traditional security concepts based on national sovereignty and territorial security have increasingly been brought under review. Currently, a broader definition of security that would incorporate non-traditional threats and their causes, including environmental stress, has been advocated. Most current research indicates that global environmental change and its subsequent socio-economic effects are likely to continue and intensify in the future. The intensity as well as the interdependence of these problems will have affects not only at local scales, but also on an international scale and will begin to impact developing and industrialized countries more directly. These challenges call for mutual cooperation at the international level which provides for multi-disciplinary integration of both technical and policy-making individuals involved in the areas of environment, development of natural resources, foreign relations, and security.

Desertification is recognized as a process of land degradation in arid, semi-arid, and dry sub-humid areas that is the result of natural phenomena (e.g. climate variation) and human-induced factors. The outcome of this type of degradation has typically been considered to be either a reduction or a loss of biological and economic productivity. The scope of the workshop included identification of the physical processes of desertification specific to the Mediterranean Region. Additionally, it was our intent to examine how changing environmental conditions may potentially reduce stability and peace in the world and thus affect "environmental security."

It is a great challenge for both scientists and decision-makers to include all of these considerations, interpret the impacts, and effectively communicate the importance of the results to a diverse audience. As a direct result of increasing discussion and research about the potential for large, regional-scale environmental changes and also the general acknowledgment of the relationship between environmental change and human social, economic, and demographic issues, there is now more attention paid to the relationship between environment and security. Thus, "*how environmental degradation in arid, semi-arid, and dry sub-humid lands (i.e. desertification) in the Mediterranean Region is related to human security*" became the central issue of the workshop.

For the purpose of this workshop the organizers engaged the Mediterranean countries that included 7 NATO Member countries, 3 NATO Partner countries, and 7 countries that comprise the Mediterranean Dialogue in the Middle East and North Africa for discussion of the issue. The region has a long historical record of political, economical, and cultural division and subsequently a long period of human occupation and resource utilization. The central importance of the topic and its relation to security attracted a large and diverse participation; over 225 participants from 22 different countries registered for the workshop. During the workshop an array of government diplomats, security specialists, and social and physical scientists from the Middle East, North Africa, Europe, and North America reviewed the actions of past and current Mediterranean land use practices, especially in regard to environmental security, environmental consequences, and challenges for the future.

The concept of the workshop was to examine desertification as an issue with cultural, political, social, and economic importance and consequences. The workshop was organized into five topical sessions dealing with implications of Mediterranean desertification (Southern and Northern perspectives); consequences of degradation on social, economic, and political issues (especially food security and human migration); soil and vegetation monitoring techniques and programs; water resources and management; and forecasting techniques and advanced technologies. Additionally, four special sessions designed to facilitate and encourage the participation of attendees were organized. They included the following topics: 1) possibilities for stopping desertification (main constraints and problems); 2) combating the lack of societal perception of desertification threats (improving communication); 3) international cooperation on sustainable development as a key issue to stop human displacement from Africa to Europe; and 4) the role of new technologies and traditional knowledge to alleviate famine and poverty.

Specifically, the objectives of the NATO Desertification Workshop were eight-fold:

1. To provide a focus on land degradation in arid, semi-arid, and dry sub-humid areas (i.e. desertification) within the Mediterranean Region;
2. To bring together interdisciplinary technical experts and decision/policy-makers throughout both the northern and southern Mediterranean States;
3. To recognize that there are remarkable demographic differences between the North and South Mediterranean and thus there are different socio-economic disturbance gradients as well as climatic gradients that affect environmental condition, sustainability of resources, employment, poverty, migration, and ultimately, security.
4. To evaluate the consequences of desertification to security both in regard to the ability of the environment to provide important ecological goods and services and relative to social and political instability;
5. To open discussion on the issue of linking security to environmental condition throughout the Mediterranean Region and to explore likely impacts on the social, economical, and political dimensions of human society;
6. To increase the knowledge base and provide assistance in developing mitigative measures and policy to thwart social and environmental instability;

7. To encourage interdisciplinary research especially in regard to integrating social and natural science;
8. To promote better mutual understanding and friendly relations across the region.

The workshop has been made possible through the active cooperation and participation of experts from government, academia, private industry, and non-governmental organizations from the NATO member and partner countries and the seven member countries of the Mediterranean Dialogue. The workshop provided a multi-lateral forum for cooperation, information exchange, and dialogue among the environmental, development, foreign and security policy communities. Additionally, it provided an "enabling environment" to facilitate joint work programmes, e.g. bridging the Regional Implementation Annexes for Africa and the Northern Mediterranean within the UN Convention to Combat Desertification. The organizers recognize the importance of understanding the linkages between the environment and security in the Mediterranean and the importance of having open discussion which is inclusive to all those who inhabit the region. It has been our sincere hope and belief that this small effort represents the beginning of a larger process intended to bring environmental and societal stabilization to the area and thus will help advance the cause of peace. We would like to acknowledge and thank all those who participated in the NATO Desertification Workshop including those who not only provided expertise through the presentation of papers but to all those who engaged in discussion and contributed their organizational support and planning assistance in making the workshop a success.

December 2003

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The NATO Workshop, “Desertification in the Mediterranean Region: An Issue of Security” was a success due, in part, to the individuals and organizations participating in it. But it was the hard and diligent work of a number of people who really made it happen. We often don’t recognize that when a four day meeting goes smoothly, when the audiovisuals work perfectly, when the programs are well written, when dignitaries from many countries and international organizations arrive, give their key note speeches, and depart with effortless precision, that this is due to the hard work and organization of numerous people. It is these people that the organizers of the Symposium and editors of this Proceedings owe a tremendous debt of gratitude. Deniz Beten, NATO CCMS Programme Director, came up with the idea to combine the CCMS (Committee on the Challenges to a Modern Society) with the NATO Science Committee (SCOM). Without her perseverance and diligence, the workshop would never have happened. In addition to Deniz, we particularly appreciate and acknowledge the efforts of Sabina Asins Velis who served as Technical Secretary for the Advanced Research Workshop on Desertification and Oscar González Pelayo who served as Technical Editor for this volume. Additionally, we acknowledge the important contributions of Vicente Andreu, Julian Campo, Artemi Cerdá, Eugenia Gimeno, and Eva Lopez, from the Centro de Investigaciones sobre Desertificacion (CIDE) of the Universitat de Valencia, Alison Trapp from the NATO Science Committee, and Martine Deweer from the NATO CCMS. These individuals, who worked mostly behind the scenes, are the ones who truly made the Symposium the success it was.

PART I. INTRODUCTION

Desertification in the Mediterranean Region: Linking Environmental Condition to Security

INTRODUCTION: DESERTIFICATION AND SECURITY

Perspectives for the Mediterranean Region

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This book focuses on two basic concepts: *security* and *desertification* in the Mediterranean Region and their linkages. It emerged from a single meeting of the "Workshop on Desertification in the Mediterranean Region. A Security Issue" held in Valencia, Spain on 2-5 December 2003, which was sponsored by the NATO Science Committee and NATO Committee on the Challenges of Modern Society.

The workshop was organized into five special sessions dealing with consequences of degradation on social, economic, and political issues (especially food security and human migration); soil and vegetation monitoring techniques and programs; water resources and management; and forecasting techniques and advanced technologies. The workshop provided a multi-lateral forum for cooperation, information exchange, and dialogue among the environmental, development, foreign and security policy communities within the Mediterranean Region and the chapters that follow reflect the important presentation and discussion of that engagement.

Desertification is recognized as a process of land degradation in arid, semiarid, and dry subhumid areas that is the result of several factors, including human activities and climate variation (UNCCD, 1999). Desertification is a worldwide phenomenon estimated to affect 40 million km^2 or approximately one-third of the Earth's surface area and 1 billion people in over 110 countries (or about one-fifth of the human population of the world) (UNCCD Secretariat, Fact Sheet 1, 2002). For the purposes of he workshop and this book, desertification was treated as an issue with cultural, political, social, and economic importance versus solely as an

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environmental problem. The purpose of the workshop became twofold: 1) to open discussion on the issue of linking security to environmental condition throughout the Mediterranean Region to explore likely impacts on the social, economical, and political dimensions of human society and 2) to evaluate the consequences of desertification to security both in regard to the ability of the environment to provide important ecological goods and services and relative to social and political instability. To undertake this discussion required the recognition that there are remarkable demographic differences between the North and South Mediterranean and thus there are different socioeconomic disturbance gradients as well as climatic gradients that affect environmental condition, sustainability of resources, employment, poverty, migration, and ultimately, security.

THE GEOGRAPHICAL SETTING

Quite easily there are a number of definitions on what constitutes the Mediterranean Region and subsequently the definitional boundaries vary from a climatic zone, a sea, a political border, and even a biogeographical area corresponding to the distribution of the olive (*Olea sp.*) (Brauch, H.G., 2003). Human perception of the environment can take any one of a variety of social, economic, scientific, and political constructs depending on purpose and need. For the purpose of the workshop and the issue of how environmental degradation in arid, semiarid, and dry subhumid lands in the Mediterranean Region is related to human security, the organizers utilized a political construct for discussion which included seven NATO Member countries, three NATO Partner countries, and seven countries that comprise the Mediterranean Dialogue in the Middle East and North Africa (Figure 1).

Geographically the area connects three continents, culturally it is the origin of three of the major world religions, and economically it once was the center of world civilization. Nevertheless, the region also has a long historical record of political, economical, and cultural division and subsequently a long period of human occupation and resource utilization.

Aside from the convenience of utilizing political borders as a framing boundary for discussion the true reality is that the appropriate spatial scale in which to deal with both the environment and security concerns may not necessarily be the nation-state. Desertification processes operate at multiple scales and although the discussion of this environmental issue occurs more frequently at the local or site level of scale where the knowledge base is greatest, the issue before this conference breaches across the entire region. Thus, the challenge before the conference assembly was to identify the linkages between the regional causes and physical processes of desertification and the consequences of past and future land use, especially as they relate to international security.

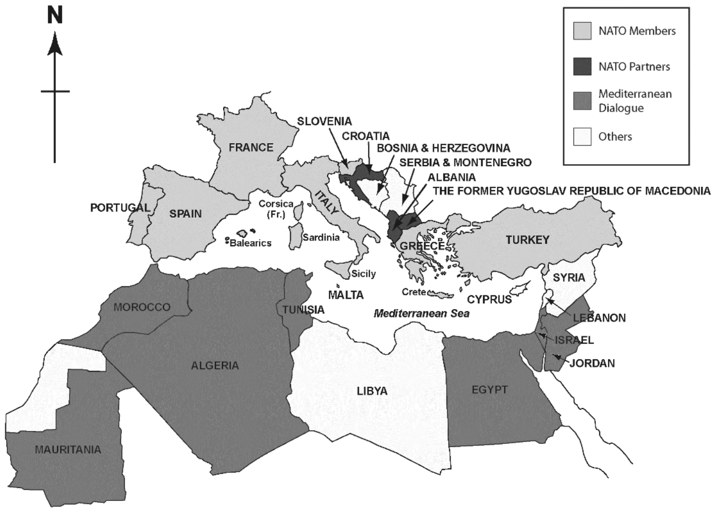

Figure 1. NATO-affiliated countries within the Mediterranean Region of southern Europe, North Africa, and the Middle East

THE ENVIRONMENTAL SETTING

Desertification as defined as land degradation in arid, semiarid, and dry subhumid areas represents actual reduction or loss of biological and economic productivity caused by land-use change, physical process, or their combination. Although these ecosystems in the Mediterranean Region are vulnerable to numerous threats, including pollution from current or past anthropogenic activities, the overwhelming threat is from human population density and associated uncontrolled development. Subsequently this can lead to depletion or degradation of natural resources (water, soil, biota) and the situation of resource scarcity which can result in human migration. The issue is confounded by the fact that there are huge demographic differences between the North and South Mediterranean, which represent different socioeconomic disturbance gradients across the region.

In the past, issues of desertification and security in the Euro-Mediterranean area have been addressed as geographically and topically uncoupled subjects. Several previous conferences have been convened, which synthesized available information for their geographies, e.g., southern Europe, but with no intent of integrating their approach across the entire region (Balabanis P., D. Peter, A. Ghazi, and M. Tsogas, 1999; Brandt, C.J. and J.B. Thornes, 1996; Briassoulis, H., M. Junti, and G. Wilson, 2003; Burke, S. and J.B. Thornes, 1998; Geeson, N.A., C.J. Brandt, and J.B. Thornes (Eds.), 2002; Grenon, M. and M. Batisse, 1988; Grenon, M. and M. Batisse (Eds.), 1989; Mairota, P., J.B. Thornes, and N.A. Geeson (Eds.), 1998; Nasr, M., 2003). This is especially apparent within the United Nations Convention to Combat Desertification, which has divided its implementation strategy into separate annexes for Africa and the northern Mediterranean but fails to provide a formal mechanism to integrate the work or link across the Mediterranean Region (UNCCD Secretariat, Fact Sheet 11, 2002; UNCCD Secretariat, Fact Sheet 14, 2002).

Root causes of desertification have been identified as population growth and climate change which contribute to the nature and extent of environmental stress. Environmental stress represents both environmental degradation and scarcity of natural renewable resources. Both factors are interconnected and thus can affect each other and represent drivers for social, economic, and political consequences. Poverty, food insecurity, forced displacement, migration, impoverished health conditions, and disruption of social and political institutions (sometimes resulting as a catalyst for conflict) are considered the important consequences of environmental stress. Environmental stress associated with desertification is a dynamic process with various levels of intensity and has been associated with at least six input factors (Table 1) that act as key drivers for regional environmental change for the Mediterranean Region (Brauch, H.G., 2000).

Table 1. Factors associated with regional environmental change within the Mediterranean Region (adapted from Brauch, 2003)

Variable *population growth* in the northern vs. southern Mediterranean
Impact of *climate change* due to increased temperatures and decline in precipitation
Scarcity of water for potable consumption and irrigation
Decline in food production and the increased dependence on imported goods, e.g., cereals
Progressive soil erosion, salinization, and *sodification*
Increased urbanization in major metropolitan areas

THE SOCIOPOLITICAL SETTING

The relationship between environmental change, stress, and desertification in the Mediterranean Region relative to the issue of security has garnered increased importance as new challenges have emerged since the end of the Cold War. The question of the relationship between environment and security is now a common interest among both the scientific and policy communities, especially as the traditional security concepts based on national sovereignty have been revisited following changes in the European political landscape at the end of the last century. The definition of security now at least incorporates nontraditional threats and their causes, including environmental stress, and social, economic, and environmental factors are now being factored into an evolving definition.

In addition to lost income (estimated annually at $42 billion [USD] at the global level) for desertified areas, there are enormous social costs (UNCCD Secretariat, Fact Sheet 3, 2002). Desertification exacerbates water scarcity, famine, internal displacement of people, migration, and social breakdown and thus provides a prescription for political, social, and economic instability which can sometimes lead to tension between neighboring countries and armed conflict. It is a challenge for both scientists and decision-makers to include these considerations into the new definition of security especially considering that multiple factors can act alone or in combination to produce various impacts associated with human or natural disaster, migration, socio-political crises, or conflict (Figure 2).

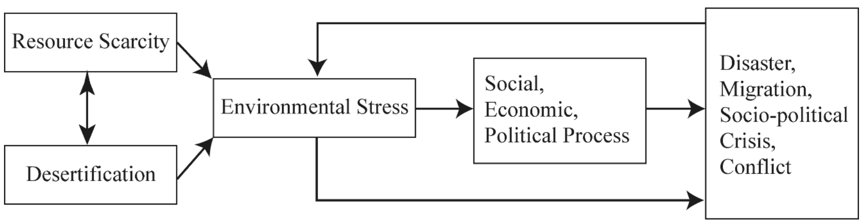

Figure 2. Conceptual relationship between environmental stress and social, economic, political, and demographic consequences (adapted from Brauch, 2003)

The NATO Workshop on Desertification in the Mediterranean Region recognized the importance of understanding the linkages between the environment and security in the Mediterranean and hopefully has made some progress to that end. More importantly it represents a commitment for developing a Trans-Mediterranean mechanism for further discussion on this topic. At one level it represents an integration between scientific and diplomatic process. At another level it brings new hope and opportunity for environmental and societal stabilization to an area that has endured a long history of human occupation and environmental change.

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DESERTIFICATION – A NEW SECURITY CHALLENGE FOR THE MEDITERRANEAN?
Policy agenda for recognising and coping with fatal outcomes of global environmental change and potentially violent societal consequences

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ABSTRACT

Desertification (representing soil degradation) is one of the three nature-induced (climate change, hydrological cycle) and of three primarily human-induced challenges (population growth, urbanisation and food) of global environmental change. These six components closely interact and contribute to fatal outcomes: primarily to extreme weather events and hydro-meteorological disasters (drought, flash floods, storms) and environmentally-induced migrations. These two fatal outcomes may have – in some cases – societal repercussions that may trigger or contribute to domestic, regional and international crisis and conflicts and thus they may become an issue of both human, societal, national and international security. To illustrate the causal linkages: for example in Morocco in the 1980s and 1990s, the following chain of events could be observed: severe drought, increase in food prices, hunger riots, general strikes, the police and armed forces interfered to repress these violent upheavals and subsequently hundreds of casualties could be deplored. These cases were not listed as a conflict in the relevant conflict data bases.

The paper is organised in three parts: In the first part, the complex casual interactions among six factors of global environment change, two fatal outcomes and three societal repercussions: crises, conflicts and conflict avoidance, prevention and resolution will be discussed. In the second part, different security concepts will be reviewed that may be of relevance for dealing with desertification as a security issue. In the third part, possible security relevance pro-active political strategies will be considered, to avoid, and prevent that desertification issues can pose security challenges, and to contribute to a resolution of the desertification driven violence.

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Drought and desertification threaten the livelihood of over
1 billion people in more than 110 countries around the world.
Kofi Annan

RESEARCH QUESTION AND BASIC CONCEPT

Is desertification a security issue? This question requires a clarification of the two concepts: “desertification” and “security”. To discuss desertification in terms of security, the interactions between desertification and other human- as well as human- and nature-induced factors of global environmental change (GEC), the resulting environmental scarcity, degradation and stress must be analysed taking also into account possible fatal outcomes of GEC, especially hydro-meteorological natural hazards, such as drought (storms and flash floods that intensify soil erosion by wind and water) and the resulting famine, environmentally-induced migration, societal crisis and in the worst case different forms of conflicts. First, the two key concepts: “desertification” (1.1.) and “security” (1.2.) will be introduced, the causes and assumed impacts of desertification on society will be reviewed in general terms (1.3.) specified for the Mediterranean (1.4.), and finally an overview of the chapter (1.5.) will be offered.

Definitions and Concepts of Desertification

Monique Mainguet (2003: 645) distinguished four meanings of desertification in the 20th century: a) in the scientific world, b) in the United Nations framework, c) in the media and d) in politics. Over time the reference to the cause of desertification changed. While Lavauden (1927) claimed: “Desertification … is purely artificial. *It is only the result of man*. It is relatively recent, and could still be fought and checked by average very simple human beings.”In response to the severe drought in the Sahel, UNEP in its *Plan of Action to Combat Desertification* (PACD) defined in 1977:

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]

In 1990, the UNEP *ad hoc* group for the "Global Evaluation of Desertification" used this definition: "Desertification is land degradation in arid, half-arid and dry sub-humid areas *resulting from opposite human impact*".

The *United Nations Conference on Environment and Development* (UNCED) in Rio de Janeiro in 1992 adopted this definition: "Desertification is land degradation in arid, half-arid and dry sub-humid areas, resulting from various factors, *including climatic variations* and *human activities*." Here, the Charter of the Earth was proposed and the negotiation of a Convention to Combat Desertification (UNCCD) was launched. According to Mainguet (2003: 646-647) both

> definitions admit that land degradation is a continuous phenomenon, leading to the reduction of potential of resources, but they omit two key-notions: the *heterogeneousness of desertification*, both in its causes, mechanisms and consequences. …. The second definition dilutes human responsibility and, as the first, neglects the different degrees of severity of degradation, in particular its ultimate degree, the *irreversibility*, as the foundation of desertification. Irreversibility should be defined in the framework of one generation: when the generation that destroys the soil is unable to rehabilitate it for economic and/or technical reasons and/or due to lacking political will (Mainguet 1991, 1994, 1995, 2003:646).

Mainguet (2003: 647) argues if *desertification* is used as "a synonymous with definitive degradation of lands", referring to *irreversibility* and to completely sterile areas, then, according to Dregne (1983), only 0.2% of our planet would be affected. Thus, "according to a scientific consensus, the term *desertification of lands* is reserved for a degradation of localised soil exclusively in drylands".

The text of the *United Nations Convention to Combat Desertification* (UNCCD) of 17 June 1994 that entered into force on 26 December 1996 used the definition of UNCED. According to Art. 1 (b) "*combating desertification*" aims at: "(i) prevention and/or reduction of land degradation; (ii) rehabilitation of partly degraded land; and (iii) reclamation of desertified land". *Drought* is used for "the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that

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1-UNEP, Status of Desertification and Implementation of the United Nations' Plan of Action to Combat Desertification, UNCED Part I, 1996.

adversely affect land resource production systems.” The task of “mitigation the effects of drought” (Art. 1, d) implies improved drought prediction “to reduce the vulnerability of society and natural systems to drought”.

The objective of the UNCCD (Art. 2) is twofold to “combat desertification” and “to mitigate the effects of drought”, especially in Africa with “long-term integrated strategies” aiming at “improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources, leading to improved living conditions, in particular at the community level”.[2]

Definitions and Concepts of Security

Security (lat.: *securus* and *se cura*; it. *sicurezza*, fr.: *sécurité*, sp.: *seguridad*, p.: *segurança*) was introduced by Cicero and Lukrez referring initially to a philosophical and psychological status of mind. The term was used since the 1st century as a key political concept in the context of ‘Pax Romana’. Dictionaries associate ‘security’ with many meanings that refer to frameworks and dimensions, apply to individuals, issue areas, societal conventions, and changing historical conditions and circumstances. Thus, security as an individual or societal political value has no independent meaning and is always related to specific individual or societal value systems and their realisation (Brauch 2003: 52).

As a social science concept, “*security* is ambiguous and elastic in its meaning” (Art 1993: 821). Arnold Wolfers (1962: 150) pointed to two sides of the security concept: “Security, in an objective sense, measures the absence of threats to acquired values, in a subjective sense, the absence of fear that such values will be attacked”. According to Art (1993: 820-22): “to be secure is to feel free from threats, anxiety or danger. Security is therefore a state of the mind in which an individual … feels safe from harm by others.” While objective factors in the security perception are necessary they are not sufficient. Subjective factors have influenced security perceptions in the Mediterranean. Due to the anarchic nature of international relations, “a concern for survival breeds a preoccupation for security”. For a state to feel secure requires “either that it can dissuade others from attacking it or that it can successfully defend itself if attacked”. Thus, security demands sufficient military power but also many “non-military elements …

2-UN, United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (Bonn: UNCCD – Geneva: WMO, March 2003): 7-8.

to generate effective military power". For Art, security involves "protection of the environment from irreversible degradation by combating among other things, acid rain, desertification, forest destruction, ozone pollution, and global warming". And he concludes "environmental security has impelled states to find cooperative rather than competitive solutions" (Art 1993: 821).

While the North, NATO and EU members, are militarily (defence spending, military hardware etc.) and economically (GDP) stronger in relation to the Southern and Eastern parts of the Mediterranean, nevertheless in subjective terms the perception of *uncertainties*, of *risks* and new *challenges*, *vulnerabilities* or *threats* has increased in Europe, and in the United States, where different perceptions and assessments have existed on the urgency of a missile threat and the need for technical responses (Brauch 2003a, 2003b).

Complex Causes and Impacts of Desertification on Society and Politics

The UNCCD Secretariat noted that today "drylands … are being degraded by overcultivation, overgrazing, deforestation, and poor irrigation practices. Such overexploitation is generally caused by economic and social pressures, ignorance, war, and drought". Thus, "desertification undermines the land's productivity and contributes to poverty", with "fertile topsoil, vegetation cover, and healthy crops" as the first victims. The UNCCD Secretariat listed among the consequences of desertification, i.e. a reduction of the land's resilience to natural climate variability, a decline in soil productivity, loss of vegetation, increased downstream flooding and reduced water quality, decline in crop yield and food production that in poor countries often contribute to famine that "typically occurs in areas that also suffer from poverty, civil unrest, or war. Drought and land degradation often help to trigger a crisis, which is then made worse by poor food distribution and the inability to buy what is available".[1]

The UNCCD has also pointed to the enormous social costs in Africa, where "many people have become internally displaced or forced to migrate to other countries due to war, drought, and dryland de-gradation. … Difficult living conditions and the loss of cultural identity further undermine social stability". For the affected poor countries, desertification "is a huge

[1] UNCCD Secretariat, Fact Sheet 1: "An Introduction to the UNCCD" and Act Sheet 3: "The consequences of desertification" (Bonn: UNCCD, March 2002).

drain on economic resources". The UNCCD secretariat estimated the global annual income forgone to about US$ 42 billion each year and pointed also to indirect economic and social costs outside the affected areas due to "the influx of 'environmental refugees' and losses to national food production".[2]

The UNCCD secretariat also addressed the manifold interactions among desertification, global change and sustainable development, acknowledging that "the interactions between these issues [sustainable development, climate change, biological diversity, water resources, energy source, food security, and socio-economic factors] are often not fully understood, but are clearly important". While climate change could worsen the effects of desertification, desertification itself may temporarily affect climate change. It claimed that "desertification exacerbates poverty and political instability", stating:

> It contributes significantly to water scarcity, famine, the internal displacement of people, migration, and social breakdown, This is a recipe for political instability, for tensions between neighbouring countries, and even for armed conflict. Evidence is mounting that there is often a strong correlation between civil strife and conflict on the one hand and environmental factors such as desertification on the other.[3]

With regard to Africa (see Annex I), the UNCCD secretariat stated that two thirds of the continent is desert and dryland, with the Southern shore of the Mediterranean being severely affected. Poverty often forces people to over-exploit marginal land, and when the land is exhausted the people are often "forced into internal and cross-border migrations, which in turn can further strain the environment and cause social and political tensions and conflicts. … Food security can ultimately be put at risk when people already living on the edge face severe droughts and other calamities."[4]

In the Northern Mediterranean (see Annex 4) land degradation has been often linked with "poor agricultural practices". As a result, soils often become "salinized, dry, sterile, and unproductive in response to a combination of natural hazards - droughts, floods, forest fires - and human-controlled activities, notably overtilling and overgrazing". Modern intensive

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[2] Ibid., Fact Sheet 3.

[3] UNCCD Secretariat, Fact Sheet 10: "Desertification, global change, and sustainable development" (Bonn: UNCCD, March 2002).

[4] UNCCD Secretariat, Fact Sheet 11: "Combating desertification in Africa" (Bonn: UNCCD, March 2002).

agriculture and the growth of industry and tourism have put coastal areas under stress.

However, these general statements on linkages and claims of causality are not yet all supported by research in the social sciences (Brauch 2003: 65-92; Homer-Dixon 1999, Bächler *et al*. 1996). One shortcoming, of the first three stages of research on environment-security linkages has been that both the interactions among causes of global environmental change (in the natural sciences), and societal consequences (in the social sciences) has been lacking.

Desertification in the Mediterranean

Soil degradation and desertification in the arid- and semi-arid areas of the Mediterranean region, as well as water scarcity, drought, flash floods and severe forest fires have been common features for centuries primarily due to human action. In the Mediterranean very degraded and degraded soils prevail. In economic terms, the Mediterranean is a major dividing line, with differences in per capita income of 1:10 or 1:15 between EU South European countries and most *Middle East and North African* (MENA) countries, but also between Israel and its Arab neighbours.

The EU-sponsored research project MEDACTION on "Mediterranean desertification" saw in land degradation: "the complex interplay of diverse unfavourable biophysical and socio-economic factors within particular socio-environmental settings [that] sets in motion various processes of *land use change* that, in turn, through proximate causes of change, activates processes of *land cover change* which may result in land degradation and desertification".[5] As human decisions and activities directly influence these processes, public policies play a pivotal role "with the use of economic, financial, natural, human, and other resources". The analysis of this interaction of human agents (farms and state agencies) requires "an integrated, cross-scale, approach to the study of the socio-spatial and socio-environmental structures within which human-resource relationships develop".[6]

The report distinguished for the Northern Mediterranean context between *drivers* (socio-economic, cultural and institutional forces) and

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[5] European Commission, Mediterranean desertification. Framing the policy context, Research results (Luxembourg: Office for the Official Publications of the European Communities, 2003): 3

[6] Ibid., 4.

proximate causes (resource users and management practices) of desertification. Among the *drivers* the report noted, urbanisation, international migration, changes in social values, structure and consumption patterns and progress in production and technology; market factors, legislative fragmentation, lack of spatial planning legislation, and the lack of implementation of laws on water resources. The EU's Common Agricultural Policy (CAP) "has spurred agricultural intensification in water-deficient areas with unsuitable soils that has led to serious erosion in the arid zones of Mediterranean Europe". Among the *proximate causes* the report noted: "overgrazing, deforestation, forest fires and land management practices" as the most direct human actions "that have triggered or intensified processes of land degradation and desertification in Mediterranean Europe" (p. 11).

Mendizabal and Puigdefábregas (2003: 687-701) in their analysis of the impacts of population and land use changes on desertification in Southern Europe and in the Maghreb[7], concluded that

> during the 20th century pure climate factors were rarely responsible for desertification in the Mediterranean, because droughts are relatively short. If natural and agricultural ecosystems are affected but not degraded, they will recover easily. Socio-economic disturbances, particularly when they occur combined with climatic fluctuations, should be considered as the main drivers for desertification in the area.

They argue that desertification in the Mediterranean basin is driven primarily by "the synergy between two *exogenous root causes*, markets and agricultural policies and climate factors and an *endogenous root cause*, demographic changes". Furthermore, "water scarcity, food security-agriculture-land use and urbanisation-pollution also affect desertification, interactively with the main factors, in a decreasing order of importance". Due to the strong North/South climatic and socio-economic gradients they distinguished two desertification diagnoses for the Western Mediterranean:

- In Southern European countries, markets and regional agricultural policies are the key desertification drivers. Major land use changes associated to desertification risk are (i) new irrigation developments, (ii) expansion of traditional tree crops over marginal lands, and (iii) sheep overstocking in localised but relevant rangeland areas. Main effects are increasing soil erosion rates, soil and aquifer salinisation, as well as degradation of fluvial and wetland ecosystems. Because of the overall increase of the non-

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[7] The smaller Maghreb comprises Morocco, Algeria and Tunisia, while the larger Maghreb includes Libya and Mauritania.

agricultural area and its vegetation density, a reduction of total water resources and an increase of wildfires start to be recorded.

- In the Maghreb countries, demographic growth, together with national agricultural policies, concerned with sedentarisation and food security, are major desertification drivers. Associated land use changes are (i) the encroachment of marginal agriculture upon rangelands and (ii) sheep overstocking of the rangelands. Mediterranean steppes are the most affected ecosystems, because they are used as buffers for the environmental impacts of agricultural policies, and lack from specific conservation strategies. Recorded effects are soil and vegetation degradation, as well as loss of biological diversity and of soil carbon sinks (Mendizabal/Puigdefábregas 2003: 701).

In the above sources only one reference pointed to food security. Most analyses on soil degradation and desertification avoid any conceptual linkage to or conceptualisation of security.

Analysing Desertification as a Security Challenge for the Mediterranean

After a definition of both key concepts the widening and deepening of security will be reviewed that have been suggested by scientists since the 1980s, and used by policy makers in national governments and international organisations since the 1990s (2).

Two concepts are of particular importance: the focus on the *environmental dimension of security* and a *human security perspectives* as well as sectoral security concepts that have been widely used by international organisations, such as *energy* (IEA), *food* (FAO), *health* (WHO) and *livelihood security* (OECD). It is argued that only in this wider use of these specific security concepts, soil erosion, degradation and desertification pose manifold security challenges, although – except in very few extreme cases – no direct hard security military threats (3).

With my model I try to illustrate possible linkages between nature and society, the environment and security, input and output factors, or between independent, intervening and dependent variables. The goal is to analyse fatal societal outcomes that may be caused, triggered or influenced by desertification, and to assess these outcomes in terms of specific security concepts (4).

Soil erosion, degradation and desertification may contribute to environmental scarcity (water, soil, food) and degradation (water and soil), as well as environmental stress that may influence, impact, trigger as one among several factors – taking the specific national and international context into account – violent societal outcomes (5). In addition, climate change has already resulted in an increase of extreme weather events and especially of the fatalities and economic costs from hydro-meteorological hazards (6).

Desertification may contribute to the intensity and length of periods of drought. It is the impact of these two natural – partly human-induced and economically driven – factors on famine and distress migration that causes *environmental, human, food, health and livelihood security* issues (7).

The relevant policy questions are:

a) How can the processes of soil erosion, degradation, and desertification be successfully contained, countered, delayed or stopped?
b) How can the societal consequences: famine, distress migration and in some cases the development of conflict constellation be curbed, and the impact be reduced by early warning and rapid action (humanitarian aid)?
c) How can the policy implementation be improved and corruption be curbed that the humanitarian aid reaches the most affected people fast whose survival is at stake?

This poses the questions of the instruments and actors for dealing with desertification as a security issue, i.e. to reduce the violent societal consequences (8).

Early recognition and perception of the urgency of the desertification challenge and its consequences (drought and famine) as security issues partly depends on the mindset and the worldview of the observer. This poses different tasks for *political* and *military security*: conflict avoidance and prevention with the tools of *development* and *environment* to enhance resilience by sustainable development to achieve environmental, human, food, health and livelihood security (9).

Thus, the dual task is to focus on the causes, triggers as well as on the violent outcomes. However, this requires a mainstreaming of activities of coping with environmental hazards and conflict prevention and avoidance. There is no simple strategy to counter and combat desertification and its fatal outcomes but a complex set of strategic components in different action plans by different national and international, societal and economic actors. Knowledge creation and anticipatory and reactive learning can become important tools (10).

WIDENING AND DEEPENING OF SECURITY CONCEPTS SINCE 1989

Security is a basic human goal. Its meaning depends on the mindset and worldview of the observer but also on the specific global context and the prevailing conflict constellation.

Worldviews and Schools in the Social Sciences on Security Issues

Behind most debates in international relations theory three intellectual traditions or worldviews have been used by the English school (Wight 1991; Bull 1977: 24-27; Watson, 1992; Brauch 2003: 53):

- the *Hobbesian* (1651) or *Machiavellian* (1531) pessimist focusing on power politics;
- the *Kantian* (1795) optimist focusing on values and norms, especially on international law;
- the *Grotian* (1625) pragmatist or internationalist pursuing cooperation.

During the cold war John Herz (1950, 1959) coined the Hobbesian term of a *security dilemma* with which he referred to the propensity of countries "to acquire more and more power to escape the impact of power of others", a tendency that has resulted in a vicious circle of mutual arms build-up.

This author has argued that the emerging new global challenges of the 21st century may require a new international order based on a Grotian *survival dilemma* (Brauch 1996, 2000, 2003, 2004, 2006) that may necessitate additional multilateral cooperation in international security (arms control, terrorism) and environmental regimes (climate, desertification, water), in international and supranational organisations. Thus, the zero-sum games of many realist approaches in the Hobbesian tradition of the 19th and 20th century must be replaced by non-zero-sum games where all major players should aim at the creation of conditions for the survival of humankind (Axelrod 1984).

If such a "*survival dilemma* is more than an idealist construct of good intentions, effective mechanisms for an efficient implementation of adopted norms and goals and a comprehensive verification regime for effective sanctions against violators is needed" (Brauch 2000: 286). Such policies require a widening of the scope and an increase in the competence and effectiveness of multilateral international organisations and regimes both in the security and environmental realm.

Security has also been a key concept of two competing schools based on different macro theories and understanding of social science: of a) *war, military, strategic* or *security studies* often with a praxeological focus (Booth 1994, 1987, 1998), and b) *peace and conflict research* that has focused at negative (war prevention) or positive peace (Galtung 1969). After the end of the East-West conflict the distance between both schools has narrowed or often disappeared.

Widening of the Security Concept in the Social Sciences and in Politics

Since the early 1990s, scientists and policy makers have broadened the security concept. Buzan, Wæver and de Wilde (1998) have distinguished between the *wideners* that called for an issue-driven widening of the security dimension by including an economic and environmental dimension and the *traditionalists* focusing on the primacy of a narrow military security concept.

They distinguished among five levels of analysis of: *international systems*, *international subsystems*, *units*, *subunits* and *individuals*. They may also be referred to as the five vertical levels of security analysis: a) global or planetary, b) regional, c) national, d) societal and e) human security (UNDP 1994). They referred to the military, the environmental, the economic, and the societal and political sector or security dimension. In addition a sectoralisation of security has occurred in several international organisations as health (WHO), energy (IEA), food (FAO), and livelihood security (Table 1).

Table 1. Vertical Levels and Horizontal Dimensions of Security, (Brauch 2003: 55)

Security dimension ⇒ Level of interaction (reference point) ⇓	Military	Political (domestic, international) (*Homeland*)	Economic	Environmental ⬇	Social
Human ➔			Energy **food**	**food, health, livelihood**	
Societal/Community					
National	U.S. and MENA focus		European focus (NATO, EU countries)		
International/Regional					
Global/Planetary ➔			energy	**food**	**health**

While most European (EU and NATO) countries have a adopted a wider security concept in their declaratory and operational policy, most countries in the MENA region still adhere to a narrow political and military security concept (Selim, 2003; Kam, 2003; Aydin, 2003). While the Clinton Administration has introduced an environmental security dimensions (NATO, 1999), the Bush Administration returned to a more narrow military and created a new domestic homeland security perspective.

Only for a wide security concept the question of desertification as a security issue can be discussed. According to Bjørn Møller (2003: 278) any widening must reply to these questions:

a) *Security of whom*? This points to the “referent” of security: state, human groups or individual;
b) *Security of what*? Depending on whose security is at stake, security may have completely different connotations;
c) *Security from whom*? This refers to the source of threat (Table 2).
Møller (2003: 279) discussed three additional sets of questions:
d) *Security from what*? Depending on that values that are threatened by whom (or what), these threats may appear in different dimensions, such as the military domain, the environment, or the economy.
e) *Security by whom*? This asks for who should do security which has an international and a sub-state dimension.
f) *Security by which means*? This question points to strategies and concrete plans, determining the relative importance of military and other means to the end of security (Table 2).

Table 2. Expanded Concepts of Security, (Møller 2003: 279)

Label	Reference object	Value at risk	Source(s) of threat
National Security	The State	Sovereignty Territorial integrity	Other states (Substate actors)
Societal security	Nations Societal groups	National unity Identity	(States), Nations Migrants, Alien culture
Human security	Individuals Mankind	Survival Quality of life	State, Globalization, Nature
Environmental security	Ecosystem	Sustainability	Mankind

In this chapter I will analyse from a human security perspective, soil degradation, desertification, drought and famine for the environmental security dimension, focusing on the individual human being as the referent, and the cause for and often also the victim of the fatal consequences of processes of global environmental change that have also implications for regional, national and societal security (Table 3). From a human security perspective "desertification" will be conceptualised for the environmental security dimension as a challenge for food, health and livelihood security (Table 1).

Table 3. Conceptualising Desertification as a Human and Environmental Security Issue

Security dimension ⇒ Level of interaction ⇓	Military	Political	Economic	Environmental ↓ Security	Social
Human →				Cause & Victim	
Societal/Community				**Desertification as a security issue**	
National					
International/Regional					
Global/Planetary →				↑ **GEC**	

Sectoral Security Concepts: Food, Health and Livelihood Security

Food Security calls for access "for all people to enough food for an active and healthy life" (FAO 1996: 265-266). It requires the adequacy (1) of food availability (effective supply); (2) of food access (effective demand); and (3) the reliability of both. Desertification and drought affect the supply side of food security. This concept has been widely used by food and agricultural and development communities, especially by FAO, WFP, OCHA, ECHO, and development and humanitarian NGOs.[8] For food security, a food system should be characterised according to Barraclough (1991) by the following.

- The capacity to produce, store, and import sufficient food to meet basic needs for all population groups.
- Maximum autonomy and self-determination (without implying self-sufficiency), which reduces vulnerability to international market fluctuations and political pressures.
- Reliability, such that seasonal, cyclical, and other variations in access to food are minimal.
- Sustainability, such that the ecological system is protected and improved over time.
- Equity, meaning, as a minimum, dependable access to adequate food for all social groups.

Food security does not imply self-sufficiency in food, a goal that is unachievable in many arid and semi-arid regions with high population growth, but it requires both sufficient food availability (supply) and access to satisfy the demand.[9]

In the MENA region, this goal can only be achieved by increasing imports of key food commodities (cereals, meat). The FAO (2003: 68) forecast that MENA countries will become even more dependent on cereal imports. Their net cereal imports are expected to rise from 49 MT (million tonnes) in 1997/99 to 116 MT in 2030 while their self-sufficiency rate has dropped from 83% (1964/66) to 63% (1997/99) and will further decline to 54% by 2030. North America, Western Europe, and Australia would have to increase their net exports from 142 MT in 1995/97 to 280 MT by 2030 to fill the demand.[10]

Health Security (WHO) requires a guarantee of accessible and affordable health care to all. WHO has used the concept as *Global Health Security* (Epidemic Alert & Response) for a global partnership: a) to contain

[8] Food security concept users.
[9] In preparation for the *World Food Summit* of 1996, the F.A.O. (1996) published three volumes on food security. Most of these dealt with food insecurity and with the inadequacy of food production to meet nutritional needs.
[10] F.A.O., Food and population: F.A.O. looks ahead, available at <www.FAO.org/News/2000/000704-e.htm>, last accessed on 5 August 2002

known risks, b) to respond to unexpected, c) to improve preparedness.[11] The major agents to enhance health security have been WHO and its affiliates, the humanitarian organisations OCHA and ECHO as well as humanitarian and development organisations including NGOs.

Both concepts of *food* and *health security* have been used in the U.S. – especially since 11 September 2001 – with a different meaning in the framework of the "war against terror" referring to efforts to avoid terrorists attacks against crops, harvests and food supplies, and water safety with chemical and biological agents as well as to avoid and to counter the spread of infectious diseases by bioterrorists.[12]

The concept of *Livelihood Security* has been widely used in Third World countries, but also by the development assistance community, and by humanitarian aid organisations as a "missing link" between poverty, environmental degradation and conflict. A IUCN project description wanted to promote environmental security "by improving livelihood security through strengthening the rights of natural resource dependent communities to the resources on which their livelihoods are based". CARE UK has defined *household livelihood security* as a model

> that puts people at the centre and examines the complex ways in which people live. Livelihoods describes how people access resources, what gets in the way of access, how resources are used to build assets such as land, savings, skills and family and community relationships, and crucially how assets reduce people's vulnerability to stresses, such as ill health, or disasters. A livelihoods approach is a useful tool for understanding complex issues and for charting the links between disasters and development. Most importantly of all, the start and end points are vulnerable people themselves.[13]

Based on experience in South Asia, N. Azad has defined *household livelihood security* as:

> access, entitlement and equitable distribution to all (at all times) commensurate with the roles performed, the time spent and the energy used (…) towards

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[11] WHO sources.

[12] See Moodie/Taylor (2000). [Moodie, Michael; Taylor, William J, Jr., 2000: *Contagion and Conflict. Health as a Global Security Challenge* (Washington: CSIS & CBACI).].

[13] See Care: "Household Livelihood Security", at: http://www.careinternational.org.uk/cares_work/how/hls.htm; T.R. Frankenberger: "The household livelihood security concept", in: http://www.fao.org/docrep/X0051T/X0051t05.htm: "The household food security approach that evolved in the late 1980s emphasized both availability of and stable access to food. Interest centred on understanding food systems, production systems and households' access to the food supply over time. It was recognized that food is only one factor in the malnutrition equation; dietary intake and diversity, health and disease, and maternal and child care are also important".

achieving livelihood security. HFS is attained through the autonomous and equitable decisions, choices and cultural preferences of households (…) concerning the deployment of resources, all of which lead to improved livelihoods, well-being and empowerment.[14]

Desertification may be conceptualised simultaneously as a *food*, as a *health* and as a *livelihood* security issue. Wind and water erosion, desertification and land degradation may cause, trigger or contribute to drought, a major hydro-meteorological hazard, while other related hazards, such as severe storms, flash floods and forest fires may intensify the process of desertification.

The UNCCD secretariat acknowledged desertification as a major *food security challenge*, particularly for Africa. Drought, as a fatal outcome of both desertification and extreme weather events, often causes low crop yields, bad harvests and in countries with a high degree of poverty, also famine that has forced people to leave their home and livelihood. The initial short-term response to famine as the end of the causal chain has been international food aid, while a medium and longer-term strategy must address the contributors to the fatal outcome by combating desertification (UNCCD), but also reducing greenhouse gas emissions (UNFCCC), by reducing both environmental (by measures of disaster preparedness) and societal vulnerability (by programmes of poverty eradication), and by increasing sustainable agricultural production (Parry, 1990).

Closely related to the food security challenge are the consequences of famine on the health of the affected people that rely on their survival on outside food aid. Famine often results in under-nourishment, malnutrition, which causes a decline in the defensive mechanism and thus a higher vulnerability to disease, and a higher rate of death among children. Thus in arid, semi-arid and sub-humid areas and in developing regions desertification has become a root cause for health insecurity, especially for the poor. In the short-term health security for the affected poor may be achieved by medical aid as part of the humanitarian assistance and in the long-term by effective strategies of sustainable development.

Desertification, drought and famine have often forced people to leave their homes, villages, provinces, in search for their individual and group survival, and to give up their traditional livelihoods, traditions and in some cases also to use their cultural identify. Thus, desertification has

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[14] See: Website of International Fund for Agricultural Development (IFAD), N. Azad: "Engendered Mobilization, the Key to Livelihood Security: IFAD's Experience in South Asia", at:<http://www.ifad.org/hfs/thematic/southasia/south_2.htm>

become an additional cause that has contributed to an increasing livelihood insecurity challenge.

In 1994, UNCCD, in cooperation with the Spanish Foreign Ministry, has addressed the linkages between desertification and migration (Puigdefábregas/Mendizábal, 1995). Strategies for improving the livelihood security are development efforts to enhance the resilience of the affected poor and local strategies for sustainable agricultural and economic development.

Desertification as a contributing cause for but also as an affected result of hydro-meteorological hazards has contributed to both food, health and livelihood insecurity. However, these sectoral conceptualisations of desertification as a security issue are necessary but not sufficient. Rather a more fundamental conceptualisation is needed that focuses from a human-centred *perspective (human security*) on interactions between human beings as a major cause for but also as victims of global environmental change. This requires an analysis of the environmental security dimension (*environmental security*).

ENVIRONMENTAL SECURITY LINKAGES AND HUMAN SECURITY CONCEPTS

Three Phases of Environmental Security Research

In the social sciences three phases of research on environmental and security linkages (on environmental and ecological security) may be distinguished (Brauch, 2003: 92-120) for the past two decades (1983 – 2003):

- During a *first conceptual phase* (1983-1990), the environmental security dimension was added to the U.S. national security agenda at the suggestion of Ullman (1983), Myers (1989), Mathews (1989) *et al*. In 1987, the Brundtland-Commission in its final report introduced both the new concepts of "sustainable development" and "*environmental security*" to the international environment and development agenda. In 1987 Gorbachev introduced the concept of *ecological security* to the UN Security Council, while a German-American NATO CCMS study tabled "Environment & Security in an International Context" on NATO's agenda in 1999 (Brauch, 2003). In the Kiev process, OSCE, UNEP and UNDP applied the environmental security concept to the Balkans and Central Asia.

- During the *second empirical phase* (1991-1999) two research teams in Toronto headed by Homer-Dixon (Homer-Dixon, 1999, 2000; Homer-Dixon/Blitt, 1999), and in Berne and Zuerich, headed by Bächler and Spillmann (Bächler, 1995, 1999, 1999a, 1999b, 1999c; Bächler/ Spillmann, 1996a, 1996b; Bächler/ Böge/ Klötzli/ Libiszewski/ Spillmann, 1996) conducted more than thirty case studies that focused on the causal relationships between environmental scarcity and conflict (Homer-Dixon) while the Swiss group focused on both environmental degradation and scarcity as well as on conflicts and conflict resolution.
- Since the mid 1990s many research teams contributed to a conceptual widening and deepening, partly relying on modelling, management efforts and focusing on the conflict potential of resource use, state failure, and on syndromes of global change. During this *third phase* many methodological approaches on aspects of the international environmental security debate could be observed, however, hardly any integration of the empirical results has occurred (Brauch 2003: 92).

Towards a Fourth Phase of Research on Human and Environmental Security and Peace (HESP)

According to Dalby (2002, 2002a: 96) environmental security "can now move to a fourth stage of synthesis and reconceptualisation". Brauch (2003: 92, 124-134; 2003c: 941-953) has suggested a *fourth phase* of research on "human and environmental security and peace (HESP)" that should combine the natural (climate change, water, soil) and the human dimensions (population growth, urbanisation/pollution, agriculture/food) of global environmental change with its fatal outcomes and its potentially violent societal consequences (migration, crises and different conflict constellations).

During the first three phases of environmental security research desertification was not analysed as an environmental security issue. Brauch suggested focusing in the fourth phase of research on the linkages among the six factors of a *survival hexagon* (including soil erosion and degradation, desertification and deforestation). This requires an analysis of the interactions between the ecosystem and humankind, on the impact of climate change, desertification and the hydrological cycle (supply factors) on environmental degradation, and of increasing demand factors (population growth, urbanisation, agriculture/food) on environmental scarcity that interact and contribute to environmental stress. In this regard the causal chain between: Climate change > extreme weather events > drought > famine > migration > crises and conflicts requires special attention. In this regard the complex interactions between climate change and desertification (Williams/Balling, 1996) are of special importance.

For an analysis of desertification in the context of the environmental security dimension the referent object is the ecosystem (GEC), the value at risk is sustainability and the source of threat is man-kind, i.e. the policies, economic production processes and wasteful consumption patterns in the North, and the poverty prevailing in many parts in the South. This refers to the nature- and human-induced (anthropogenic) processes contributing to environmental stress.

Concepts of Environmental and Ecological Security

During the 1990s, the concepts of *environmental* (Westing, 1986, 1997) or *ecological security* (Rogers, 1997; Mische, 1998; Lonergan, 2002), have been widely discussed by scientists, governments and international organisations primarily from the vantage point of Grotian perspectives that calls for cooperative and multilateral solutions but hardly from Hobbesian views that have adhered to narrow, primarily military security concepts focusing on threats, strategies, missions and hardware solutions, nor from a Kantian view that warned against a militarisation of the environment .

The narrow Hobbesian concepts of *military security* defined in terms of national interests can contribute little to understanding these non-military challenges and their likely impact. Since the 1980s, several co-operative security models have been proposed, and since 1990, cooperative security efforts gradually replaced the competitive security doctrines of the Cold War to cope with non-military challenges with primarily non-military means.

Arthur H. Westing (1988: 257-264) pointed to both the military impact on the environment and to environmental factors in relation to security. Johan Jørgen Holst (1989: 123-128) saw three relationships between conflict and environment: a) *environmental deterioration* (space, atmosphere, lithosphere, hydrosphere, biosphere) as a consequence of armed conflict, b) *environmental degradation* (due to poverty, injustice, population growth) as a *cause* of conflict and c) *self-reinforcing environmental degradation* (refugees, food riots, urban violence) as a *contribution* to armed conflict.

When the Cold War ended Mathews (1989) and Myers (1989, 1989a) proposed a wider security concept by addressing two key issues: “First there was a need to redefine security and to include a new range of threats. … Second, there was an acceptance that the object of security was no longer simply the state, but ranges to levels above and below the level of the state” (Lonergan, 2002 V: 270-271).

J. T. Mathews (1989: 162) proposed a “broadening definition of national security to include resource, environmental and demographic issues”. Norman Myers (1989: 23-41) pointed to several environmental factors (soil erosion, ozone layer, climate change) as legitimate causes for international concern that may have repercussions for US security policy. In his book *Ultimate Security*, Myers (1993, 1996: 12) claimed that the “principal threat to security and peace stems from environmental breakdown” and that environmental problems can “figure as causes of conflict”, such as water in the Middle East, desertification in the Sahel, water diversion or flooding in Bangladesh.

No consensus has emerged so far in the social sciences and in the political realm on the definition of environmental or ecological security. Buzan *et al*. (1990) stated: “Environmental security concerns the maintenance of the local and the planetary biosphere as the essential support system“. For Brock (1991: 408) environmental security dealt with: a) environmental depletion as a cause of violence and social conflict; b) environmental modification, and c) ecological cooperation building confidence and trust; d) military means to enforce environmental standards, e) healthy environment for comprehensive security. For Rajendra K. Pachauri (2000), the present chairman of the IPCC, environmental security requires a minimisation of environmental damage and the promotion of sustainable development.

Concepts of Human Security

According to Møller (2003) the referent of *human security* are individuals and humankind, the value at risk is the survival of human beings and their quality of life, and the major sources of threat are nature (*global environmental change*), globalisation processes, and the nation state with its ability to cope with this dual challenge. Brauch (2003: 132) referred to several meanings of human security as a) a level of analysis, b) a perspective of the analyst, c) as an encompassing concept (UNDP 1994), and d) as the outcome of human action. Human security may be most pertinent for an equity-oriented pragmatic Grotian perspective on environmental security problems (Figure 1).

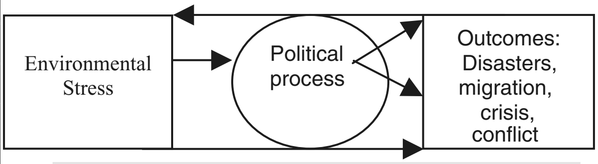
Security dimension ⇒ Level of analysis⇓		Environmental security dimension (encompassing food, health and livelihood security)
Human ➔	H	
Societal/Community	U	
National	M A	
International/Regional	N	
Global/Planetary ➔		Knowledge (reduce impact, vulnerability, increase resilience)
Security perspective		Human security perspective (poverty eradication, freedom, equity)

Figure 1. Human Security Perspective on Environmental Stress and Outcomes

A human security perspective encompasses all levels of analysis: from the individual to the planetary. As a *people-centred* concept, *human security* combines the three pillars of *development* (poverty eradication), *freedom* (human rights) and *equity* on the international and *justice* on the national level. The *human security perspective* to environmental security problems also encompasses food, health and livelihood security.For Bohle (2002) human security is a desirable outcome for individuals, communities and an active concept challenging inequitable structures contributing to insecurity and vulnerabilities.

In the political realm, the human security concept has been promoted by the governments of Canada and Japan, supported by a coalition of 13 states participating in the human security network (HSN) since 1999, among them five NATO countries: Canada, Greece, Norway, the Netherlands and Slovenia, five EU members: Austria, Greece, Ireland, the Netherlands and Slovenia, in addition to Chile, Jordan, Mali, Thailand and South Africa as an observer. This network adopted the following vision:

> A humane world where people can live in security and dignity, free from poverty and despair, is still a dream for many and should be enjoyed by all. In such a world, every individual would be guaranteed freedom from fear and freedom from want, with an equal opportunity to fully develop their human potential. Building human security is essential to achieving this goal. In essence, human security means freedom from pervasive threats to people's rights, their

> safety or even their lives. Human security has become both a new measure of global security and a new agenda for global action.[15]

The HSN emerged from the landmines campaign and was launched at a Ministerial meeting in Bergen Norway in 1999, and later conferences at Foreign Ministers level were held in Lucerne, Switzerland (2000), Petra, Jordan (2001), Santiago de Chile (2002) and in Graz, Austria (2003). The HSN:

> pursues security policies that focus on the protection and security requirement of the individual and society through promoting *freedom from fear* and *freedom from want*. … The Network's current efforts to achieve greater human security include issues such as the universalization of the Ottawa Convention on Anti-personnel Landmines, the establishment of the International Criminal Court, the protection of children in armed conflict, the control of small arms and light weapons, the fight against transnational organized crime, human development and human security, human rights education, the struggle against HIV/AIDS, addressing implementation gaps of international humanitarian and human rights law, and conflict prevention.[16]

Among its key principles are human rights and humanitarian law as the foundation for building human security

> Human security is advanced… by protecting and promoting human rights, the rule of law, democratic governance and democratic structures, a culture of peace and the peaceful resolution of conflicts. The international organisations created by states to build a just and peaceful world order, above all the United Nations, in its role to maintain international peace and security as stated in the Charter, must serve the security needs of people. ... Innovative international approaches will be needed to address the sources of insecurity, remedy the symptoms and prevent the recurrence of threats which affect the daily lives of millions of people.[17]

At a *Human Security Policy Workshop* in Santiago, Chile (13-14 May 2002), organised by the Harvard Program on Humanitarian Policy and Conflict Research (HPCR) and hosted by the Latin American Faculty on

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[15] See: “A Perspective on Human Security: Chairman's Summary 1st Ministerial Meeting of the Human Security Network, Lysøen, Norway, May 20 1999”, at: <http://www.humansecuritynetwork.org/menu-e.php>.

[16] See “The Network” at: <http://www.humansecuritynetwork.org/network-e.php .

[17] See: “Principles”, at: < http://www.humansecuritynetwork.org/principles-e.php>.

Social Studies (FLACSO-Chile) a *Human Security Index* was proposed to measure human security, and several related recommendations were made.[18]

The fifth Ministerial Meeting of the HSN in Graz, Austria (8-10 May 2003) focused on human rights education and on the role of children affected by armed conflict and adopted a mid-term work plan (2003-2005) that included efforts to strengthen international humanitarian law. At the 6th Ministerial Meeting, in Bamako, Mali, in May 2004, the HSN adopted a "declaration on food security" that stated "that food security constitutes a priority challenge for human security, that the right to food is inseparable from other human rights, and that it is a vital element in the building of human security".[19]

The Commission on Human Security (CHS) was established in January 2001 by the Government of Japan in response to the UN Secretary-General's call at the 2000 Millennium Summit for a world "free of want" and "free of fear". It was co-chaired by Mrs. Sadako Ogata (former UN High Commissioner for Refugees) and Professor Amartya Sen (1998 Nobel Price in Economics). The CHS submitted its final report on: "*Human Security Now*" in May 2003 that contained these key ideas:

> Human security focuses on *shielding people* from critical and pervasive threats and *empowering* them to take charge of their lives. It demands creating genuine opportunities for people to live in safety and dignity and earn their livelihood. … The Commission concentrates on a number of distinct but interrelated issues concerning conflict and poverty: protecting people in conflict and post-conflict situations, shielding people forced to move; overcoming economic insecurities, guaranteeing essential health care, and ensuring universal education.[20]

In its final report, the CHS (2003: 4) offered this definition of human security:

> to protect the vital core of all human lives in ways that enhance freedoms and human fulfilment. Human security means protecting fundamental freedoms – freedoms that are the essence of life. It means protecting people from critical (severe) and pervasive (widespread) threats and situations. It means using processes that build on people's strengths and aspirations. It means creating

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[18] See: "Ministerial Meetings“, at:<http://www.humansecuritynetwork.org/docs/santiago_annex1-e.php>.

[19] See: HSN, "Declaration on Food Security", at: <http://www.humansecuritynetwork.org/docs/bamako_food-e.php>.

[20] See: CHS-website: "Press Release“, at: < http://www.humansecurity-chs.org/finalreport/pressrelease.html>.

> political, social, environmental, economic, military and cultural systems that together give people the building blocks of survival, livelihood and dignity.[21]

The CHS argued that "human security" complements "state security" by having the individual and the community as the referent whose menaces are not always those of the state, by expanding the range of the actors and by "not just protecting people but also empowering people to defend themselves". Human security calls for a shift "from focusing on external aggression to protecting people from a range of menaces", such as "environmental pollution, transnational terrorism, massive population movements, such infectious diseases as HIV/AIDS and long-term conditions of oppression and deprivation". The concept is much broader than state security and shifts the focus from securing borders to "lives of people and communities inside and across these borders". The human security concept connects the "freedom from want and freedom from fear" with a "freedom to take action on one's own behalf" (empowerment) "to enable people to develop their resilience to difficult conditions". This dual goal of "protection" and "empowerment" distinguishes "human" from "state" security, from humanitarian and development work.

> Supporting people's activity to act on their own behalf means providing education and information so that they can scrutinize social arrangements and take collective action. It means building a public space that tolerates opposition, encourages local leadership and cultivates public discussion. It flourishes in a supportive larger environment (freedom of the press, freedom of information, freedom of conscience and belief and freedom to organize, with democratic elections and policies of inclusion). It requires sustained attention to processes of development and to emergency relief activities, as well as to the outcomes. The primary question of every human security activity should not be: What can we do? It should be: How does this activity build on the efforts and capabilities of those directly affected?

The report lists as special issues in human security: hunger, water, population and the environment. The latter relationship is "most pronounced in areas of human dependence on access to natural resources" that are critical for the livelihoods and the survival of people. "When these resources are threatened because of environmental change, people's human security is also threatened".

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[21] CHS: *Human Security Now* (New York: CHS, May 2003), at: http://www.humansecurity-chs.org/finalreport/index.html.

> Among the more intractable and costly environmental problems is land degradation, including salinization from poorly planned irrigation systems, erosion from deforestation and agriculture, and heavy metal and other pollutants from industrial runoff. Pollution and land degradation have extensive health impacts in addition to impairing people's ability to grow food. Creeping desertification may also undermine the ability of a traditional rural community to subsist. … The stresses on the Earth's ecosystem and their effects on the human security of its inhabitants are multiple and severe. … the crucial links between the environment and human survival require more commitment to effective regulation, management and sustainable use of natural resources. Critical to this is the need to explicitly link plans for improved management and sustainable development to disaster prevention and preparedness.

For the environmental challenges of desertification and its fatal consequences of drought and famine this human security agenda implies for governments, international and nongovernmental organisations a fundamental shift in the security perception from the narrow focus on "military threats" by other governments and. terrorists to a wider conceptualisation of security. This requires moving from a Hobbesian mindset to a Grotian worldview that calls for multilateral cooperation for the *protection* of the people and their *empowerment* to enhance their resilience and coping capacity to deal with the fatal outcomes of global environmental change.

Desertification as a New Security Challenge?

With regard to *objective* or *hard security* desertification poses no military threats but as a regional environmental challenge, desertification, drought and famine severely undermine the well-being of people, and in severe cases it may even threaten the survival of individuals of affected local communities that may in the very worst case affect and undermine national stability. From a subjective perspective desertification, drought and famine contribute to environmental and human as well as food, health, and (household) livelihood insecurity.

If desertification forces people to leave their home, village and country, internal displacement, urbanisation and trans-border migration may also contribute to social insecurity with social and ethnic groups as the referent where national identity may be perceived as being at risk and immigrants are often perceived as threats that challenge the distribution of scarce resources: water, soil and food. Whether and when severe social insecurity pose a challenge or even threat to internal, domestic or national security depends on the specific national socio-economic and political circumstances, and on the international context. National (political, economic, military) security may be threatened by general strikes and hunger riots, and the value at risk may be regime stability and the survival of governments. The severe droughts and famine in the Sahel during the 1970s and 1980s has repeatedly resulted in violent clashes between nomadic tribes and resident farmers that have been associated in some cases with large trans-boundary environmentally-induced migration what has often triggered ethnic clashes.

In the early 21st century, desertification, drought and famine and the related distress migration have been perceived as human security threats by the Commission on Human Security in its final report, but they have not yet been politically addressed by the Human Security Network. However, drought and famine have been addressed as challenges to food security by the FAO, the WFP and IFAD, as well as to health security by the WHO. The Executive Secretary of the UNCCD Secretariat, Hama Arba Diallo, echoed the concern expressed by security experts at a Valencia NATO workshop, which emphasized desertification in the Mediterranean region as a security issue.

> It is widely recognized that environmental degradation has a role to play in considerations of national security as well as international stability. Therefore, desertification has been seen as a threat to human security. … Experts at the NATO workshop emphasized that desertification threatens food security, health security, environmental security and livelihood security. Environmental changes, such as desertification, put pressure on social, economic, political and demographic dynamics, triggering insecurity.

The UNCCD Secretariat has advocated a more comprehensive concept of international security, e.g. during an expert meeting on Desertification, Migrations and Conflicts in Almería (Spain) in 1994:

> 50 armed conflicts in 1994 had environmental causal factors characteristic of drylands. These are triggered by mass migration of people who have no choice but to leave their lands in search of other livelihoods once their land becomes degraded and loses productivity, exposing them to the risk of conflicts with the established populations in the new lands. Often, the environmental push element for migrations triggered by the environmental scarcity factors, is hidden behind ethnic or socio economic considerations. In fact, 135 million … are at risk of being displaced as a consequence of desertification. Some 60 million people are expected to eventually move from the desertified areas in Sub-Saharan Africa

> towards northern Africa and Europe in the next 20 years. Long term studies on West Africa project a constant migratory flow from Sahelian regions to coastal cities, whose population is expected to grow 3.5 times the numbers in 1997 to 271 million in 2020.

The UNCCD Secretariat noted that in America, annually between 700,000 and 900,000 Mexicans leave their rural dryland homes to migrate to the United States. During the last few decades in China, many villages have been lost "to expanding deserts, sand drifts, dune movement and sandstorms". From the Central Qurnah marsh (Iraq), ca. 80,000 to 120,000 may have crossed the border into Iran and 200,000 may have dispersed throughout Iraq. In Haiti, land degradation reduced the per capita grain production to half compared with the 1960s, thus contributing to chronic political unrest that contributed to 1.3 million Haitians emigrating since the 1980s.

> This problem equally constitutes an increasingly acute concern in the Mediterranean because many of the countries in Northern Africa and Southern Europe suffer from desertification. … Sixty percent of total land in Portugal and 75 percent of arable land in Turkey are at risk of desertification. Further, most of the territory in Northern Africa lies in arid and semi-arid zones, which are prone to desertification, and serve as transit zones towards Europe for migrants from sub Sahelian Africa. There is today a growing awareness that, in the context of climate change, desertification is a survival issue, including severe social and food security problem in these regions and that it must be addressed as a one of the root causes of internal strife and public insecurity.[22]

Thus, desertification is increasingly being recognised as a critical environmental and human security challenge by academic experts and many UN international organisations. Nevertheless, the political agenda setting has just started. A CIA-sponsored report (2000) on *Global Trends 2015* only referred to population growth and water scarcity as issues that pose U.S. national security concerns.

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[22] See UNCCD, Press release: "UNCCD confirms NATO concern with desertification as a threat to security" (Bonn, 19 Dec. 2003), at: <http://www.unccd.int/publicinfo/pressrel/showpressrel.php?pr=press19_12_03>.

MODEL ON GLOBAL ENVIRONMENTAL CHANGE AND FATAL OUTCOMES

The following model illustrates the possible causal links between environment and security, input and output factors, between independent, intervening and dependent variables. The goal is to analyse the fatal societal outcomes that may be caused, triggered or influenced by desertification in close interaction with the other five factors contributing to global environmental change that have been combined in a "survival hexagon" (Figure 2).

According to the definition in the text of the UNCCD, desertification results "from various factors, *including climatic variations* and *human activities*". Many experts have stressed for the 20th century primarily human factors (population growth, overexploitation of marginal land, intensive agriculture that are primarily poverty driven in the South and often market driven in the North. Many experts have claimed that climate change will increasingly have a negative impact on desertification and soil erosion processes through an increase of extreme weather events (such as an increase in severe winter storms in the North and sand storms in the deserted areas, but also forest fires and flash floods) that have resulted in an increase in wind and water erosion and soil degradation.

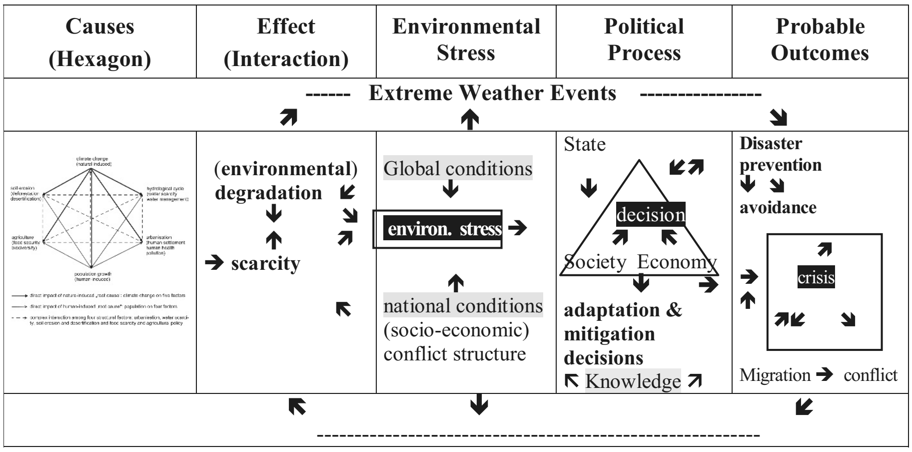


Figure 2. Model: Global Environmental Change, Environmental Stress and Fatal Outcomes

Linkages Between Desertification and Climate Change

The IPCC (1996a: 95-324) assessed in detail the climate change impacts on land degradation and desertification. On deserts, the IPCC (1996b: 161) stated with certainty that "most deserts are likely to become even more extreme if climate changes as projected by current scenarios; most desert regions are expected to become hotter", and "opportunities to mitigate greenhouse gas emissions in desert regions are few". But, the IPCC also stated that "human-induced desertification has the potential to counteract any ameliorating effect of climate change on most deserts". On the interactions between climate change, land degradation and desertification, the IPCC (1996a: 173) argued that it is often impossible to separate the impact of unsustainable land-management and climate change but often they interact and produce negative cumulative effects on soil.

- Desertification arises both from human abuse of the land and from adverse climate conditions. Climate related factors such as increased drought can lead to an increase in the vulnerability of land to desertification and to the escalation of the desertification process.…
- Changes in the frequency and intensity of precipitation will have the greatest direct effect on soils via erosion by water. … Future erosion risk is likely to be related more to increases in population density, intensive cultivation of marginal lands, and the use of resource-based and subsistence farming techniques than to changes in precipitation regimes.…
- Where conditions become more arid, salinization and alkalisation are likely to increase because evapotranspiration and capillary rise will be enhanced…
- Predicted warming may give rise to higher evaporation rates, leading to drier soils and more frequent episodes of severe wind erosion.
- Because arid and semi-arid land ecosystems have little ability to buffer the effects of climate variability … they are particularly vulnerable to climate change…

These effects are relevant for Mediterranean and MENA countries (Williams/Balling, 1996; Mainguet, 1994; Portnov/Hare, 1999; Puigdefábregas/Mendizabal, 1995).

Desertification as an Object of an Analysis of Syndromes of Global Change

For the complex interactions between human interventions and the Earth System, the German Scientific Advisory Council on Global Environmental Change (WBGU, 1996: 111; 1996a: 107) saw a major task in answering four questions: a) on the causes of these changes and how they are linked to global development problems; b) on how they can be identified and predicted at an early stage; c) what risks they involve and d) how much humankind can act to prevent negative developments at the global level and to mitigate the consequences of global change?

The WBGU argued that the disciplinary or "sectoral approach must be supplemented by a systems approach" that tries to integrate the complexity of dynamic interrelationships. As a new method for holistic analysis, the WBGU has focused first on *trends of global change*. Those of special relevance for global change (e.g. climate change, soil erosion) were selected and grouped as *core problems of global change* (climate change, soil degradation, biodiversity loss, water scarcity, overexploitation and pollution of oceans, increasing incidence of human-induced natural disasters, population growth, urbanisation and migration, food security, health, and global disparities in development). These trends and their interactions were linked in a global network of interrelations that can also be analysed for the regional level between human societies and the environment. The WBGU (1996a: 112) argued:

> These functional patterns (syndromes) are unfavourable and characteristic constellations of natural and civilizational trends and their respective interactions, and can be identified in many regions of the world. The Council's underlying theses is that complex global environmental and development problems can be attributed to a discrete number of *environmental degradation patters.* … Each one of these 'clinical profiles' of the Earth System therefore represents a distinct basic pattern of environmental degradation induced by human society.

According to the WBGU (1996a: 114) the syndrome concept offers several options: a) to permit an assessment of the vulnerability of a region to a specific syndrome; and b) by the systematic integration of "causes, mechanisms and effects as problem-specific pattern" may contribute to sound mitigation options. Prior to developing response options the identification of "the main syndromes involving disturbances to or non-sustainable forms of people-environmental relations is an essential prerequisite" (115). The WBGU-listed 16 syndromes that distinguish among: a) utilization (1-7), b) development (8-13), and c) sink syndromes (14-16) that must meet three criteria: 1) relate directly or indirectly to the environment, 2) "occur as a visible or virulent cross-cutting problem in many regions of the world", and 3) should "describe non-sustainable development and/or significant environmental degradation" (WBGU, 1996a: 116).[23]

Several of these syndromes are of direct relevance for interpreting the complex interactions among the six drivers of the hexagon, e.g. among the "utilisation" syndromes the *Sahel-Syndrome* on the overcultivation of marginal land and among the "development" syndromes the *Bidonville Syndrome* on environmental degradation through uncontrolled urban growth in the MENA region, or the *Mass Tourism Syndrome* on the development and destruction of nature for recreational ends and the *Disaster Syndrome* with singular anthropogenic environmental disasters with long-term impacts in many Mediterranean countries. Relying on this approach, Schellnhuber suggested a holistic *Earth System Analysis* (Schellnhuber/Wenzel, 1998) and integrated modelling on patterns of interactions with feedbacks.

The Sahel Syndrome: Overcultivation of Marginal Land

Both the German Scientific Advisory Council on Global Environment Issues (WBGU) and several authors of the Potsdam Institute of Climate Impact Research (PIK) wrote on the *Sahel-Syndrome* that is

> described as the overuse of agriculturally marginal land by a poor or impoverished rural population living in a context of action offering little or no alternative livelihood opportunities – thus leading to the further degradation of their environment. This syndrome typically occurs in countries on a low level of socio-economic development and in regions vulnerable to human impacts due to relatively weak agricultural production potential. This production potential can either be limited due to aridity limitations, temperature limitations or due to limiting soil-fertility conditions. … The core mechanism … of this syndrome consists of a vicious circle, relating the trends impoverishment, intensification/expansion of agriculture and soil erosion – the latter leading to productivity losses and subsequently more poverty (Schellnhuber *et al*., 1997: 10).

[23] This WBGU book may be downloaded at:
< http://www.wbgu.de/WBGU/wbgu_publications.html >.

This syndrome has been developed for the Sahel zone where “more than half the population is threatened by starvation destabilization of rural production and social systems”. Here traditional crop rotation methods have forced “an expansion of agricultural production to marginal lands” what contributed to both desertification and urbanisation. Symptoms of the Sahel Syndrome are: “destabilisation of ecosystems, loss of biodiversity, soil degradation, desertification, threats to food security, marginalisation, rural exodus”.

The disposition towards one syndrome depends on a combination of natural environmental and socio-economic characteristics. The results often indicate a close interrelationship between poverty that produces more agricultural activities that contribute to soil degradation causing renewed increases in poverty (Schellnhuber *et al*., 1997: 10-12). Lüdeke, Moldenhauer and Petschel-Held (1999: 315-328) analysed the complex interactions between poverty driven soil degradation under climate change in the framework of the *Sahel Syndrome* (Figure 3), focusing on a twofold linkage to syndromes: a) syndrome-specific mechanisms may contribute to climate change; and b) regions that are presently not affected by the syndrome may become prone to its effects in the course of a future climate change. In contrast to the Sahel zone, the MENA region has not been threatened by starvation because the declining self-sufficiency in food (Collomb, 2003, Alexandratos, 2003, Chourou, 2003) has been compensated by increased food imports, especially of cereals.

Many symptoms of the Sahel syndrome already apply to the MENA regions, but “virtual water” (Allan 2003) has been and may remain a key instrument to avoid its direct (famine) and indirect (conflicts) consequences. The Sahel syndrome is relevant for the analysis of the complex trends and interaction among nature- and human-induced drivers of regional environmental change in the MENA area where desertification, rapid urbanisation and migration, and declining food self-sufficiency have been progressing during the 20th century. For this region this syndrome poses questions whether the projected regional climate change may lead to vicious circles that have existed in the Sahel for decades (Mainguet 2003; Mendizabal/Puigdefábregas 2003).

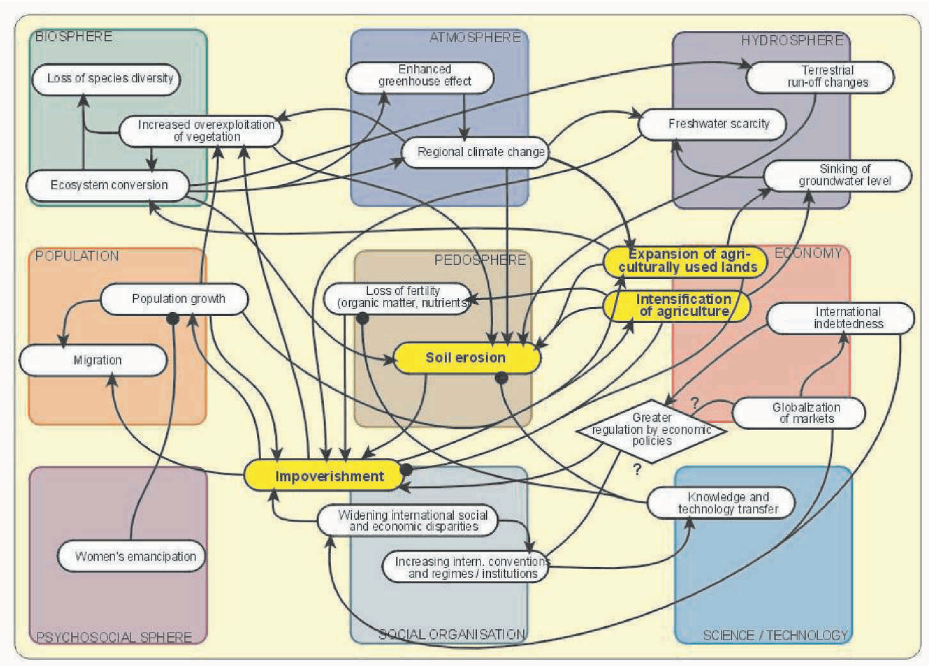


Figure 3. Specific Network of Interactions in the Sahel Syndrome. Ellipses in yellow indicate the major dynamic kernel of the overall mechanism, (WBGU, 1996, printed with permission)

DESERTIFICATION AS AN ELEMENT AND CAUSE OF ENVIRONMENTAL SCARCITY, DEGRADATION AND STRESS

The Sahel syndrome shows the complex interactions between natural and human factors of global environmental change. Geographically this requires a focus on those regions with a high degree of soil degradation, as well as on arid, semiarid and sub-humid areas that are specifically susceptible to progressing enlargement of deserts (ecological hotspots).

In our own model (Figure 2) the “survival hexagon” illustrates the manifold interactions between desertification and the five other factors of: climate change, hydrological cycle but also by the three demand factors: population growth, food and housing and urbanisation (Figure 4).

Desertification has been a major contributor to environmental degradation, scarcity and stress as a hydro-meteorological hazard drought: is a cause of famine, hunger revolts, migration that may cause, trigger or contribute to domestic crises and in extreme cases also violent conflicts. Environmental and human security are directly affected by these interactions among the drivers of global environmental change.

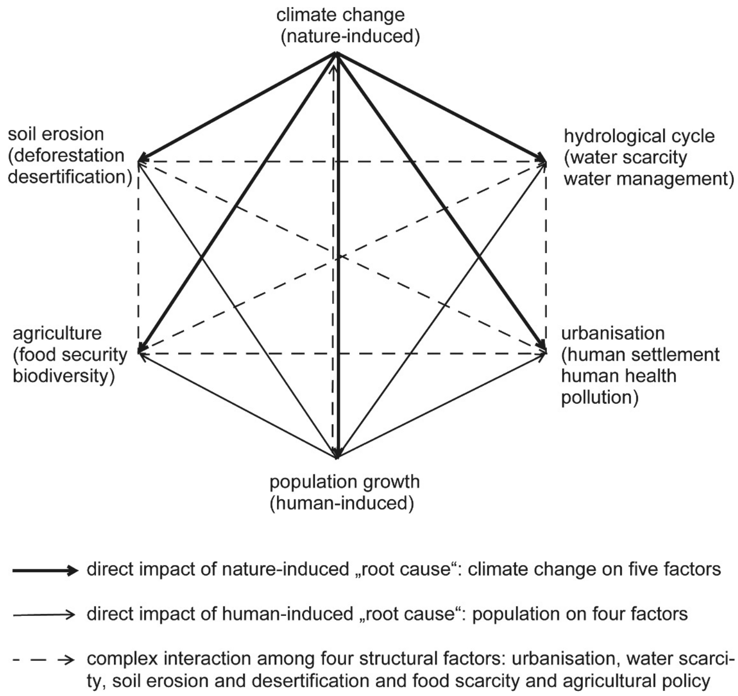


Figure 4: Survival Hexagon

Economic production and consumption patterns on both shores of the Mediterranean are influenced by economic globalisation and they impact on Global Environmental Change (GEC). GEC may increase environmental vulnerability to drought that is associated with a scarcity of water and food what often results for the poor in arid and semi-arid regions in famine, and drought-induced migration. Globalisation often contributes to inequity that maintains or increases existing social or societal vulnerability that also trigger migration and in some cases lead to ethnic conflict.

It is doubtful that these complex and often combined environmental and socio-economic challenges can be solved by the military. However, military services can be used – and in some cases have been successfully used to combat desertification (e.g. Tunisia).

INTERACTIONS AMONG FATAL OUTCOMES

Concepts and Data Sources

Our model (Figure 2) has distinguished between two major fatal outcomes: a) hazards and disasters and b) migration and three different societal repercussions: c) crises, d) resolution and thus a prevention or an avoidance of conflict constellations and e) eruption of violent conflicts. Both on the outcomes and on the societal repercussions two groups of data must be distinguished:

- *Structural data*: e.g. statistics, indexes, data bases on hazards and natural, biological, hydrometeorological, geophysical, technological and intended terrorist human disasters;
- *Situational* data: e.g. information on specific cases (field reports of humanitarian organisations, press reports, government reports, case studies etc.) as well as earth observation data on the impact of natural hazards and disasters.

In the literature much knowledge exists on the individual factors of drought, migration, crises, and conflicts. But there is a lack of systematic knowledge on linkages among these fatal outcomes, e.g. between drought and drought-induced migration or between famine and hunger-driven migration, and between migration and violent conflicts and conflict-induced migration (Brauch, 2002, 2003d, 2003e).

Natural Hazards and Disasters

On natural disasters one of the best statistical source is the EM-DAT OFDA/CRED International Disaster Database of reported events provided by the Centre for Research on the Epidemiology of Disasters (CRED), at the University of Louvain, Belgium. EM-DAT covers all reported disasters, from 1900 to the present, for natural and technological disasters that are organised by countries. Munich Re keeps a country archive on disasters (Cat PML Service).

Environmentally-Induced Migration

The terms "environmental refugees", "environmental migrants" and "environmentally-induced migration" have been widely used in the political and scientific literature. Norman Myers (1995, 2002: 214-218) has claimed that in 1995 there were 25 million environmental refuges compared with 23 million traditional refugees (Black, 2001). However, there are major problems with the term environmental "refugee" because neither in international legal conventions nor in national immigration, asylum or internal security laws accept "environmentally-induced causes" for granting a refugee status. The definitional problems imply that environmental refugees are not reported as a special case neither in national nor in international migration statistics. Instead in UN documents the concept of "environmentally-induced" migration has been used. How are these considerations reflected in major international research and statistical surveys?

Most statistical sources, e.g. published by the UN, OECD, and the EU, do not include a category of "environmental refugees", "environmental migrants" and "environmentally-induced migration" (Cohen, 1995).The *International Migration Report 2002* of the Population Division of the UN estimated about 175 million migrants that represented about 3% of the world population but there was no single reference to "environmental refugees".The United Nations Fund for Population Activity (UNFPA), in its report on: *Population and Environmental Change* (2001) included a general reference to environmental refugees without statistical evidence. In its 2002 report on: *People, Poverty and Possibilities*, the UNFPA gave no data on "environmental refugees", nor on "environmentally-induced migration".The OECD, in its annual reports on *Trends in International Migration* (e.g. SOPEMI, 2001) did not discuss the issue and supplied no statistical data. Nor did theU.S. Committee for Refugees in its *World Refugee Survey* list such a category.The UNHCR/IOM/RPG (1996) published a report of an: *International Symposium: Environmentally-Induced Population Displacements and Environmental Impacts from Mass Movements* that avoided the term "environmental refugees". El-Hinnawi (1985) defined "*environmental refugees*" as:

> those people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption (natural and/or triggered by people) that jeopardised their existence and/or seriously affected the quality of their life.

Swain (1996) rejected this term and preferred to use the concept of *"environmental migrants"*:

> [for persons who] are forced to move away from their homes as a result of the loss of their livelihood and/or living space because of environmental changes (natural as well as anthropogenic) and who are forced to migrate (temporarily or permanently) to the nearest possible place (within or outside the state boundary) in search of sustenance.

In the Report on the UNHCR/IOM/RPG symposium the concept "environmental refugees" was not used, instead the term "*environmentally displaced persons*" was used and defined as:

> Persons who are displaced within their country or habitual residence or who have crossed an international border and for whom environmental degradation, deterioration or destruction is a major cause of their displacement, although not necessarily the sole one.

Environmental change (both natural and manmade) is a recognised cause of migration while migration has also become a cause of environmental change. The report on the UNHCR/IOM/RPG symposium distinguished among several categories of "environmentally-induced population movements": a) acute onset movements, with or without the possibility of return; b) slow onset movement, with the possibility of return; c) slow onset movement with predictability (for example, displacement caused by large-scale development projects) but with no possibility of return because of human activities; d) slow onset movement, without the possibility of return due to the natural conditions of the area.

To summarise, there seems to be an emerging consensus that natural disasters contribute to distress migration, disasters cause temporary or permanent migration, while migration may intensify disasters due to a high societal vulnerability (Suhrke, 1996, 1997). Whether and to which extent this interaction has contributed to societal crises and conflicts will be discussed next.

Environmentally-Induced Crises and Environmental Conflicts

Domestic and international crises have generally been defined in international relations as turning points between peace and war. During the Cold War the main research has been on systemic, international, governmental crises (Hermann, 1993: 205). Michael Brecher (1993) defined crisis as a: a) change in type, intensity of disruptive interactions between states, with a probability of military hostilities; b) destabilisation of a relationship where 3 criteria are relevant: (i) high stakes; (ii) finite time for response; and (iii) military hostilities. These prevailing concepts of "crisis" in political science and international relations are linked to the "security dilemma" of states.

They cannot explain the environmentally-induced socio-economic, societal and political crises that are associated with the "survival dilemma" (Brauch, 2000, 2004, 2006) of individuals and of affected societal groups. For environmental crises different criteria apply: a) they may result from environmental stress due to scarcity and degradation and extreme weather events, b) they are either rapid onset (hazards) or slow onset (temperature increase and sea-level rise), c) their impact is both temporal and local (rapid onset hazards and disasters) and long-lasting and global (low onset global environmental change), and d) their societal repercussions are rather low-level and domestic violence (strikes, revolts, distress violence) and only in the most extreme cases they result in military hostilities between countries.

Kriesberg (1996: 122) argued that "conflict permeates all aspects of human interaction and social structure, fights or struggles such as wars, revolutions, strikes, uprisings". Each of the existing conflict and war databases has used different definitions of conflicts (Mack, 2002: 523-524) and wars that make it impossible to compare the data systematically. The Kosimo database (HIIK) defined conflict:

> as the clashing of overlapping interests (positional differences) around national values and issues (independence, self-determination, borders and territory, access to or distribution of domestic or international power); the conflict has to be of some duration and magnitude of at least two parties (states, groups of states, organizations or organized groups) that are determined to pursue their interests and win their case. At least one party is the organized state.[24]

[24] Brauch, 2003: 112-115; HIIK, see at: <http://www.hiik.de/>.

The Hamburg working group on causes of war (AKUF) defined an armed conflict as a: “violent confrontation where the definitions of war do not fully apply where a continuity of battle does not yet exist”. AKUF defined war as. “a) a battle among two or more armed forces (military, paramilitary forces, police units); b) where on either side a centrally controlled organisation exists, c) where armed operations regularly occur”. They distinguished among five types of wars: a) anti-regime, b) secession, c) interstate, d) decolonisation, and e) other internal wars with or without the involvement of third parties.[25] Peter Wallensteen (Uppsala) defined an armed conflict as: “a contested incompatibility which concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths”.

These three definitions do not apply to low-level environmentally-induced conflicts where on behalf of the victims no central organisation or armed forces exist, and no regular armed operations occur. So far neither a generally accepted definition of an “environmental conflict” exists nor an empirical data base on “low-level violence”. At present, only the new *PRIO Center for Study of Civil War* in Oslo will systematically analyse environmental causes of conflicts (Gleditsch/Wallensteen/Eriksson/ Sollenberg/Strand, 2002; Brauch, 2003c: 115-116).[26]

Data Quality and Research Needs on Linkages between Outcomes and Societal Consequences

What is the quality of the *structural* data in the disaster and conflict databases? On disasters, CRED is the best statistical source but the major problem has been the unequal quality of reporting and the different intensity of coverage. Munich Re supplies important data on the economic damages and on the insured damages caused by disasters. “Environmental refugee” is no operational and legally accepted term and thus no detailed statistical evidence exists. But environmentally-induced migration has become a real challenge, irrespective of these obvious definitional and statistical problems.

With regard to crises, most evidence refers to international crises of

[25] Brauch, 2003: 112; AKUF, see at:
<http://www.sozialwiss.uni-hamburg.de/Ipw/Akuf/home.html>,

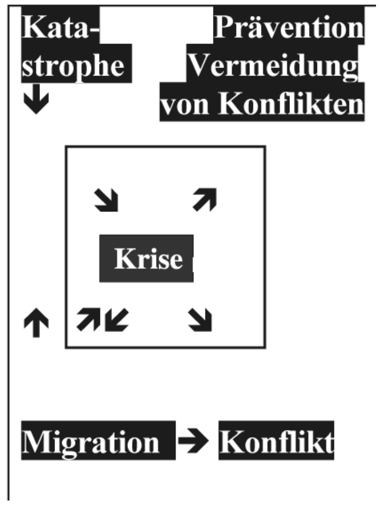
[26] See PRIO annual report of 2003 (Oslo: PRIO, 2004).

the type of July 1914 or of the Cuban Missile Crisis, but little systematic evidence exists on environmentally-induced domestic crises.

With regard to conflicts, all definitions of existing databases exclude events of low-level violence, e.g. the case of the hunger and bread revolts in Morocco of 1984 and 1990 are missing in all databases. With regard to environment and conflict links, two causal chains must be distinguished:

a) *Starting with natural causes*: a lack of precipitation ➢ drought ➢ bad harvests ➢ famine ➢ disaster-induced migration ➢ clashes between migrants and resident farmers ➢ or hunger riots ➢ police and armed forces restore order often using force what results in casualties.
b) *Starting with societal outcomes*: conflicts ➢ war refugees ➢ famine ➢ increased societal and environmental vulnerability of war refugees to hazards and disasters (drought, floods, epidemics).

Desertification contributes to the first causal chain (input factor) while soil degradation may be intensified by both causal chains. If there are linkages between hazards and conflicts, then a mainstreaming of efforts for an early warning of hazards and of conflicts makes sense. Let me summarise these linkages in five working hypotheses:



Thesis 1: There is a linkage between processes of Global Environmental Change and hazards leading to disasters.

Thesis 2: The IPCC (2001) observed and projected a linkage between climate change and an increase in extreme weather events resulting in an increase in number and intensity of hydro-meteorological events.

Thesis 3: Munich Re observed an increase in economic damage from hydro-meteorological disasters for 1950-95 (Vellinga/ Mills 2001).

Thesis 4: There exists a complex interaction between drought and environmentally-induced, disaster-triggered migration.

Thesis 5: In some cases hazards and disasters and environmentally-induced migration may cause, trigger or contribute to domestic and international political crises that may under certain conditions escalate to violent conflicts what should be avoided, prevented or resolved (inter)nationally by adaptation and mitigation strategies.

Figure 5. Interaction among Fatal Outcomes

DESERTIFICATION-INDUCED DROUGHT, MIGRATION AND FAMINE AS SECURITY ISSUES

Desertification is a slow-onset environmental challenge to security and survival, especially for the poor in the arid, semi-arid and sub-humid regions of the world. Desertification, drought and famine affect the individual, family, livelihoods, village, tribe, ethnic group, the region and the state. They impact on the survival of the rural population and contribute to rapid urbanisation. In some affected developing countries desertification, drought and famine are part of a vicious circle: Poverty contributes to desertification and desertification often intensifies poverty. Thus, there exists a complex dual cause and effect relationship. Drought, migration and famine are situational challenges to security and survival, especially for the poor. For centuries drought as a hydro-meteorological hazard (that has been partly caused (the degree is disputed among the specialists) by climate change and its interaction with desertification – and will most likely increasingly be influenced by this interaction during this century – has forced people to leave their home and livelihood. Drought has often resulted in famine and/or food price increases that sometimes resulted in strikes, hunger revolts, domestic crises and conflicts.

Victims of Drought in the Mediterranean and in the Sahel

Desertification may contribute to the intensity and length of periods of drought. It is the impact of these two natural – partly human-induced and economically driven – factors on famine and distress migration that causes environmental, human, food, health and lively-hood security issues.For the Mediterranean, the available evidence illustrates the statistical problem resulting from different reporting mechanisms if the data for Spain and Morocco are compared for the years 1995 to 2001 that can hardly be representative. Obviously there has been an over-reporting with regard to the affected people in Spain and an underreporting in Morocco (Table 4).

Table 4. People Affected by Drought in the Mediterranean (1975-2001)
Source: Brauch 2003: 876.

	Total			**Drought/Famine**		
	Event	**Killed**	**Affected**	**Event**	**Killed**	**Affected**
South Europe (EU)	249	8,888	12,622,055	8	0	**6,000,000** (4 events, Spain)
Cyprus, Malta	9	59	4,451	2	0	0
Balkans	50	562	3,779,928	3	0	3,210,500
Eastern Mediterranean	95	27,613	3,700,060	5	0	988,000
North Africa	82	6,606	2,038,320	10	0	**306,400** (5 events, Morocco)
Total	**485**	**43,728**	**22,144,814**	**28**	**0**	**10,504,900**

If we include Sudan in the survey of people affected by natural hazards between 1975 and 2001, then it becomes obvious that of the 34,336,005 persons that were reported as affected about 80 % were victims of drought and famine. What diagnostic tools do policy makers, in foreign, defence, environment and development ministries as well as in international institutions (OCHA) have for analysing the assumed interactions and to select the most urgent cases for pro-active development aid to enhance resilience against disaster and to improve the conflict prevention capabilities? Two such tools will be briefly mentioned: a) ECHO's: Global Humanitarian Needs Assessment[27]; and b) The "Index of Human Insecurity" (IHI) by Lonergan and his colleagues (2000).

Human Needs Assessment and Index of Human Insecurity

Among the nine countries on the top of the ECHO's global humanitarian needs assessment (Table 5) several countries, e.g., Sudan has a high (3) occurrence of natural disasters, refugees, internally displaced persons and conflicts. However, this high occurrence of these four groups of events does not necessarily imply a causal linkage.

Whether such linkages can be observed requires structured and focused comparative case studies (George 1979) using the same methods and addressing the same questions to all cases. Such systematic knowledge may assist ECHO and OCHA to fine-tune their pro-active activities both with regard to disaster prevention and conflict prevention (short-term) and disaster mitigation and conflict avoidance (long-term).

Of the countries on the ECHO list that are most in need four are in the Nile Basin and all but Afghanistan and Bangladesh are in Africa where processes of soil degradation and desertification as well as the impacts of drought on famine have been very severe for decades. Eight of the Nile Basin countries (except Egypt) in the Sahel have experienced repeated periods of severe droughts and famine, they are the victims of a high degree of food insecurity, and have been major recipients of food aid. They also experienced both large internal displacements and manifold tribal, ethnic and religious conflicts. Resource scarcity (of land, water and food) may have contributed or triggered several of these violent conflicts but were in no case the single cause for a violent escalation (Table 5).

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[27] The document has been made available to the author by Mr. Peter Billing, head of the planning office of ECHO, European Commission. Permission to quote this document has been granted.

Table 5. Global Humanitarian Needs Assessment of ECHO. Source: P. Billing, ECHO.

Country Ranking			I		II		III		IV	
	Priority List of Humanitarian Needs	ODA	HDI	HPI	Natural disasters	conflicts	Refugees	Internal displaced persons	food	Death below age of 5
		Aver.	1	2	3	4	5	6	7	8
1	Burundi (Nile)	2,857	3	x	**2**	**3**	**3**	**3**	3	3
2	Somalia	2,833	x	x	**3**	**3**	**2**	**3**	3	3
3	Ethiopia (Nile)	2,625	3	3	**3**	**2**	**3**	**1**	3	3
4	Sudan (Nile)	2,625	3	2	**3**	**3**	**3**	**3**	2	2
5	Angola	2,571	3	x	**1**	**3**	**2**	**3**	3	3
6	Afghanistan	2,500	x	x	**3**	**3**	**1**	**2**	3	3
7	Liberia	2,500	x	x	**1**	**3**	**3**	**2**	3	3
8	Rwanda (Nile)	2,500	3	3	**2**	**3**	**3**	**0**	3	3
9	Bangladesh	2,375	3	3	**3**	**2**	**2**	**2**	2	2

One long-term early warning indicator, the projected population growth in the Nile Basin until 2050, indicates a major human catastrophe in the making that may result in severe human, environmental, food, water, health and livelihood insecurity. For the four countries among the nine most in need, the UN projects a population growth of about 180 million between 2000 and 2050 (Table 6).

Table 6. Population Growth and Projections for the Nile Basin Countries (1950-2050)

	1950	**2000**	**2050**	**2000-50**
Sudan	9,2	31,1	63,5	32,435
Ethiopia	18,4	62,9	186,5	123,544
Rwanda	2,1	7,6	18,5	10,914
Burundi	2,5	6,4	20,2	13,862
Sum (1-4)	**32,2**	**108,0**	**288,7**	**180,755**
Sum (1-9)	86,7	280,8	855,8	574,967

In their index of human insecurity, Lonergan, Gustavson and Carter (2000) argued that human security is achieved "when and where individuals and communities: a) have the options necessary to end, mitigate, or adapt to threats to their human, environmental, and social rights; b) have the capacity and freedom to exercise these options; and c) actively participate in attaining these options". They claimed three relationships between environmental degradation and human security:

i) There exists a *cumulative causality* between environment and security (e.g., environmental degradation may result in population movement that in turn poses a threat to the environment).

ii) The responses to the insecurities posed by environmental degradation may contribute to other insecurities (e.g., population movement could also threaten other aspects of human security not directly linked to the environment).

iii) Human security embodies the notion that problems must always be addressed from a broader perspective that encompasses both *poverty* and issues of *equity* (social, economic, environmental, or institutional) as it is these issues that often lead to insecurity and conflict.

Their "Index of Human Insecurity" (IHI) is to distinguish countries "based on how vulnerable or insecure they are, and groups together those countries that possess similar levels of insecurity". They selected indicators based on a set of evaluation criteria that included:

- relevance to the selection framework in that the indicator measures either key structural relationships … or key functional relationships … of the system with reference to either environmental, economic, societal, or institutional components;
- existence of a theoretical or empirical link between the indicator and insecurity;
- general availability of the data;
- consistency of the data with other selected indicators to allow for future modelling of the system; and
- adequacy of the spatial coverage based on the number of countries represented and adequacy of the time series available.

They selected four indicators each for the environment, the economy, the society and institutions. However, these indicators exclude the vulnerability to natural hazards and income distribution. To calculate the (IHI), they established first a complete time series for all indicators and all countries, then the data were standardised and, finally, the data were classified and the index calculated. The data were classified into 10 categories and countries were assigned a number between one and ten for each indicator before the IHI was calculated.

In relating the IHI to indicators of human development such as the Human Development Index (HDI) of the UNDP that comprises indicators on the level of economic development, longevity, and level of education, they found strong correlation between the IHI and the HDI and concluded that "significant increases in human security may occur with only small increases in development".

For policy purposes, the authors see two relevant applications: First, "the IHI can be linked to more specific sets of indicators (water security or food security) to assist in identifying how sector-specific problems may affect overall levels of human insecurity", and second, "the IHI can be used to project how human insecurity may change over time".

There are significant differences between ECHO's human needs index and the IHI by Lonergan and his colleagues. Lonergan *et al*. saw the highest human insecurity not for the countries in the Nile Basin but rather for countries in West Africa (Nigeria, Niger, Chad, Liberia, Sierra Leone, Guinea, Senegal), and in the Horn of Africa (Ethiopia and Somalia). While some countries are in the arid and semi-arid zones, other West African countries are not. For them the abundance of precious resources (e.g. diamonds and others) instead of scarcity have contributed to state failure and conflicts.

Almería Symposium on Desertification, Migration and Conflict

In February 1994, an international symposium on "Desertification and Migration" in Almería (Spain) addressed three focal points: (a) global interactions between desertification and migration, (b) presentations of case studies from North America, Middle East, Central Asia, Sub-Saharan Africa and the Mediterranean region, and (c) policy issues to governments and public administrations. The results of this meeting were summarised in the *Almería Statement* (1994). Falkenmark (1995: 31-40) argued that

> the combination of famine and poverty tend to generate environmentally-driven migration, both between countries and continents. Desertification, which is considered as the degradation of arid land with soils limiting nutrient- and water resources, contributes to the destabilization of the affected societies and may induce migration of the people involved. … The main threats resulting from unavoidable population growth are … the environmentally-driven migration in areas of scarce water resources, and … the problems related to water supply of over-populated cities.

Westing (1995: 41-52) pointed to the following reasons for displacements: a) race, religion, nationality, social group; b) flight from armed conflicts, c) abandonment of areas lacking sufficient sources for subsistence. The over-exploitation and over-grazing and the conversion of rangeland into crop land have caused land degradation and desertification.

He saw five sources for the socio-political impacts of environmentally-driven migration: a) at the side of origin of the displaced persons, b) at rural or urban sites (slums, bidonvilles) of destination within the country, c) in non-industrialised foreign countries and e) in industrialised foreign countries.

Leighton Shwartz/Notini (1995: 69-113) noted the thin literature on the relationship between environmental degradation and migration. In their conclusions they suggested i.a. "to establish new directions of research on desertification, both as a cause and consequence of border-crossing migrationary displacements".

Bächler (1995: 185-224) in his empirical analysis on the linkages between desertification and conflict distinguished among three approaches a) an eco-geographical, b) a transformation, and c) a marginalisation of poverty approach. In the first approach he used the eco-region (rather than the state) for analysing conflict potentials resulting from environmental degradation. He noted that in Africa desertification was a present source of conflict in 7 and a potential source in 6 cases, what amounted to 13 of a total of 21 cases (Central/South America: 4; Middle East/Central Asia: 2; South/South East Asia: 2). Bächler (1995: 212) concluded that the socio-economic effects of desertification often intensified the desertification process, and in some cases led to conflicts that escalated to wars, with environmental flight or migration as the most visible and serious consequence of desertification. Bächler (1995: 213) interpreted environmental flight or migration as the "most visible" and "most serious consequence of desertification" and water problems as the second biggest cause. Furthermore, the marginalisation of the poor in marginal land may also lead to - marginal - conflicts.

Lohrmann (1995) argued that migration in arid, semi-arid and dry sub-humid areas of Africa was the result of a combination of factors „that include drought, desiccation, poverty, inappropriate land use, ineffective laws, population growth, and civil and international war". With respect to the Sahel zone, Weiss (1992) claimed that the following factors increased the pressure to migrate: a decline in the per capita cereal production, stagnation of average hectare yields, a reduction of the arable land per capita, population growth and wars.

Desertification, Migration and Conflicts: Claims and Scientific Disputes

In 1988, about 10 million people were considered as “environmental refugees“ who were defined by El-Hinnawi (1985) as “those persons who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption that has jeopardised their existence and/or seriously affected the quality of their life“.

Myers (1993, 1995) described them as: “People who can no longer gain a secure livelihood in their homelands because of drought, soil erosion, desertification or other environmental problems, and hence are obliged to move elsewhere, however hazardous the effect“. Myers (1995: 27) discussed as the main environmental factors that cause people to emigrate: long-term environmental degradation, natural disasters, major environmental accidents, development disruptions of environments and associated factors as population growth, poverty and famine that may also be partly caused by environmental decline. For Myers “neither environmental push nor economic pull need be a wholly sufficient cause of migration”, but a number of intervening contributory factors would “not negate the link between environmental cause and migration effect”. Among them are “non-adaptive institutional structures, deficient planning systems, and disempowerment of women”.

While processes of environmental degradation due to pollution and soil erosion leading to desertification are caused by regional developments, global warming and the resulting climate change is caused by the global greenhouse gas emissions (Brauch, 1997, 1997a, 1997b, 1998, 2000/2001, 2002, 2002a, 2002b). The “Almería Statement on Desertification and Migration” (1994) noted that half of the migrants originate in Africa.

> These are largely of rural origin and related to land degradation. It is estimated that over 135 million people may be at risk of being displaced as a consequence of severe desertification. Therefore a holistic approach of local development, empowering the local population and protecting the environment within the context of a poverty-reduction strategy, should be combined with more effective migration policies in such areas.

On the socio-political dimension, the statement referred to the projected high population growth that may result in an exclusion “of vulnerable groups, who are subject to suffering, oppression, and dependency on fragile ecosystems under stress". The statement referred to conflicts in the early 1990s: "Of the 50 or so armed conflicts currently in progress, some 20 have an environmental dimension or are partly environmentally induced. Half of the latter are associated with arid lands". It argued that the

> resulting social and political turbulence, set in motion by the exploitation and degradation of natural resources, is likely to become a major factor in geo-political instability. Migration into cities or onto marginal lands accelerates the impoverishment of land, resources and people. This may lead to persistent upheaval or further migration, stimulating ethnic conflicts or social unrest elsewhere. Environmental problems created at local or regional levels and related conflicts exert ever-increasing pressures on political stability at regional levels.

The Statement called for several policy and action priorities, including research to achieve a better understanding on the "relationship between environmental degradation and migration". This research

> should seek to disaggregate primary factors motivating migration, and should quantify and analyze size, geographic origin, frequency of displacement, gender and aged data and patterns of resource use in arid lands. Surveys of dryland ecosystems should investigate the correlation between desertification, poverty and migration and become part of an early-warning system for humanitarian crises in the making. Prospective analysis of existing or future conflict potential should include a careful assessment of the differences between temporary flight and permanent migration; and between internally displaced persons, cross-boundary and transcontinental migrations.[28]

But ten years later in 2004, the empirical research on the impact of desertification on migration remains unsatisfactory. Rather, general estimates that are not substantiated by detailed statistical accounts, seem to prevail.[29] The International Association for the Study of Forced Migration (IASFM) has described forced migration as: "a general term that refers to the movements of refugees and internally displaced people (those displaced by conflicts) as well as people displaced by natural or environmental disasters, chemical or nuclear disasters, famine, or development projects".

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[28] See the text of the statement at:
<http://www.unccd.int/regional/northmed/meetings/others/1994AlmeriaSpain.pdf >.

[29] See: Norman Myers, in: Philosophical Transactions: Biological Sciences (The Royal Society) volume 357 number 1420 (2002), for a summary at: http://www.population-growth-migration.info/index.php?page=literature.html.

This group focuses on three separate, often simultaneous and inter-related, types of forced migration caused by conflicts, development and disasters with the latter including:

> people displaced as a result of natural disasters (floods, volcanoes, landslides, earthquakes), environmental change (deforestation, desertification, land degradation, global warming) and human-made disasters (industrial accidents, radioactivity). Clearly, there is a good deal of overlap between these different types of disaster-induced displacement. For example, the impact of floods and landslides can be greatly exacerbated by deforestation and agricultural activities. Estimating trends and global figures on people displaced by disaster is even more disputed and problematic than for the other two categories.[30]

In the literature the assessment of the linkages between environmental change and forced migration remains controversial. While Myers (1995) has claimed a close linkage, Black (1998, 2001) has challenged this hypothesis while Castles argued that "general forecasts and common sense linkages do little to further understanding". He suggested looking at specific cases.

> Myers and Kent discuss … Ethiopia and Eritrea, Somalia, Sudan, Rwanda, Nigeria, Bangladesh and China. … Their argumentation appears largely deductive: country X has environmental problems and also has large numbers of emigrants and refugees. Therefore there must be a causal linkage. The method seems particularly problematic when applied to future prognoses: Nigeria, they show has rapid population growth and is likely to have future problems of desertification, soil erosion and water pollution. …. Yet Nigeria is not a significant country of emigration – in fact it attracted many immigrants in the oil boom years of the 1970s.[31]

Castles (2001) claims that Myers and Kent do not specify "on what basis are environmental factors assigned primacy in complex situations". He also refers to the research by Shin-wha Lee (2001) who explored the 'environment-security nexus' and puts forward a 'model of the causes of environmental refugees' by looking in detail at Bangladesh, Sudan and North Korea.

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[30] See Forced Migration Online, Refugee Studies Centre, Oxford University, UK, at: < http://www.forcedmigration.org/ whatisfm.htm >.

[31] Stephen Castles: "Environmental Change and Forced Migration" (6 December 2001), at:< http://www.preparingforpeace. org/ castles_environmental_change_and_forced_migration.htm>; See: Castles/Miller 1998.

> In fact her model shows the complex interaction between ecological factors, human-induced disasters, governmental factors (such as inaction, incapacity and corruption, as well as harmful policies), and international factors. In the same way, all her cases studies show multiple causes of forced migration. Bangladesh, with its extremely dense population and its exposure to cyclones and flooding, appears as the quintessential example of environmental displacement. Yet even here Lee finds complex causes for impoverishment and flight, including land ownership patterns, ethnic divisions, economic development projects such as dams, and political conflicts. The action – or more often the inaction – of the Bangladeshi government is a major factor causing forced migration. Even the Indian government plays a part, since the Farakka dam on the Ganges upstream from Bangladesh did much to reduce water supply and endanger agricultural production in the Ganges delta (Lee, 2001, 73-83).

Lee stated "that both Bangladesh and North Korea illustrate Amartya Sen's principle that the roots of famine lie not in lack of aggregate food supply, but in the failure of individuals' entitlements to food. The problem is primarily political and social – not environmental". Castle concluded that the concept of *environmental refugee* "is misleading and does little to help us understand the complex processes at work in specific situations of impoverishment, conflict and displacement". For him, environmental factors "part of complex patterns of multiple causality, in which natural and environmental factors are closely linked to economic, social and political ones. This is where we need much more research and better understanding, if we are to address the root causes of forced migration."[32]

This scientific dispute had little impact on the declaratory statements of many international organisations, such as the UN Populations Fund that claimed on "Urbanisation and Migration":

> The environmental impact of massive refugee resettlement has been severe in some instances and manifested in the form of deforestation, uncontrolled tapping of ground water resources, overexploitation of land and strain on the social infrastructure. The effects of environmental changes on the population are also increasing in scope. For example, it is estimated that globally there are at least 25 million 'environmental refugees' – individuals who have migrated because they can no longer secure a livelihood from the land because of deforestation, desertification, soil erosion and other environmental problems. This environmental exodus has occurred mainly in sub-Saharan Africa, the Indian sub-continent, China, Mexico and Central America.[33]

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[32] Ibid.

[33] See: UNPF, at: <http://www.unfpa.org/sustainable/urbanization.htm>.

But the same organisation has offered no detailed statistical evidence for its quoted estimate. The World Health Organisation (10.12.2000) saw direct impacts of desertification on health in Africa, especially with regard to "malnutrition and famine, waterborne diseases, other infectious diseases, respiratory diseases and burn injuries", and a WHO official saw "sufficient evidence that desertification and drought harm human health". According to Ambassador Diallo, Executive Secretary of the UNCCD:

> Desertification and drought are directly linked to poverty, food and water shortages, conflict, mass migration, increased poverty, increased risk of fire, decreased availability of fuel and limited access to health care. …. The effects of desertification, drought and poverty can include protein-energy malnutrition intrauterine growth retardation and deficiencies of several micronutrients (such as iron and Vitamin A), infections, blindness and anaemia. … Desertification and droughts can increase water-related diseases such as cholera, typhoid, hepatitis A and diarrhoeal diseases. Malaria epidemics are also subject to rapid increases in incidence, usually related to season and population movements. The Sahel is the only dryland in the world to have experienced a long drought, with a 21% decline in annual rainfall over the past 100 years. … Furthermore, drought increases the susceptibility of some forests and rangelands to fire, often resulting in severe episodes of air pollution, which may also affect neighbouring countries. This biomass burning can cause acute respiratory disease and exacerbate chronic respiratory disease in children and adults.[34]

The link between desertification, drought and migration has been claimed in many statements by Hama Arba Diallo, Executive Secretary of the UNCCD:

> Drought and desertification seriously threaten the livelihoods of the millions of people in Africa who depend on the land for most of their needs. … Desertification also contributes to massive migration movements, conflicts, and worsening poverty. In recent years, millions of desertification-induced migrants have been forced to abandon their land and search for a means of survival in nearby urban centres or in other countries.[35]

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[34] See: "Desertification and drought greatly affects Africans' health", in: *Afrol News* (10.12.2000); at: <http://www.afrol. com/ Categories/Health/health048_desertification.htm >.

[35] See: "African Governments Reveal New Anti-desertification Strategies ", in: Jet News (Journalists Environment Association of Tanzania), Nov. 1999, at: <http://www.jet.or.tz/press_releases.htm>.

These general estimates and claims by scientists and representatives of international organisations and regimes on the causal linkages require a major social science research effort, based on clear concepts of the causes and of the fatal outcomes, substantiated statistical evidence and comparative case studies.

Research Needs on Desertification and Security Linkages

To assess the specific security aspects of the linkages between land degradation and desertification, as well as drought, hunger revolts and conflicts for the Mediterranean region major empirical work is needed on the linkages among the fatal outcomes (Figure 5). While several authors have referred to a coincidence between famine areas and major wars in the Sahel during the 1980s (Garenne, 1994), the systematic evidence for North Africa is thin.[36] Between the 1970s and 1990s there were hunger revolts in several North African countries after periods of severe drought and increases of food prices. Whether these violent events were triggered by drought, or by the pressure of the IMF to reduce food subsidies remains disputed.[37]

The economy of all North African countries, especially in Morocco, is affected by longer periods of drought, that have resulted in a drop in GDP from agriculture, and in increased cereal imports. In news articles in the European press, three cases of violence have been reported for Morocco after periods of severe drought for 1981, 1983/1984 and 1990 for which the following sequences of events may apply: Desertification has contributed to drought. The declining agricultural production and the rise in food prices have contributed to public protests (bread and hunger riots) that resulted in a general strike to which the police and army responded at the request of the government to restore order. Several hundred people were killed, wounded and arrested. None of these low-level violent events qualified as a conflict under the definition of the conflict data bases and are thus not listed. The three events between 1981 and 1990 where a causal link between drought and conflicts may exist are:

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[36] See: M. Garenne: „Mortality in Sub-Saharan Africa: Trends & Prospects“; I.L. Griffith: “Famine and war in Africa“, in: *Geography*, 73,1:59-61.

[37] See. (IHT, 17.12.2000).

- 25 March 1981: Revolts in Morocco (Casablanca): 66 persons killed, 110 injured in demonstrations against drastic increases of food prices (NZZ).
- 4 February 1983: Drought and famine; 26 August 1983: IMF negotiations and hunger revolts 1984;21 January 1984: Nador: 10.000 demonstrate against higher food prices (FR); 23 January 1984: demonstrations: 40-150 persons died; Tetuan and El-Hoceima: more than 100 deaths (RNZ, NZZ, FR);25 January 1984: Tetuan: more than 200 deaths (SZ); 26 January 1984: Moroccan opposition: 400 deaths, 100-150 in Tetuan (FAZ); 27 January 1984: government admitted: 24 to 29 deaths, 114 injured (SZ); 3 February 1984: 500 persons (mostly students) in prison (FAZ, FR); 17 February 19.84: 96 Moroccans in court for illegal call for a general strike (FR); 5 March 1984: Moroccan farmers exempted from taxes for this century (IHT);
- 17 December 1990: a general strike for higher wages in Fez and Rabat that resulted in violent riots where several persons were killed and many were injured in battles with the police (IHT).

How significant was drought as a cause or trigger of these cases of violent internal conflict? Were these bread and hunger riots triggered by IMF decisions to reduce food price subsidies? Or was the protest exploited by minority groups (Berber) to strengthen their domestic political role? None of these reported violent events are mentioned in the major conflict data bases because they do not meet the specific conflict definitions.

To develop peaceful domestic conflict resolution, prevention and avoidance strategies, collaborative North-South empirical research may be needed on the relationship among the outcomes between desertification, drought, famine, hunger revolts, migration, crises and conflicts.

INSTRUMENTS AND ACTORS FOR DEALING WITH DESERTIFICATION AS A SECURITY ISSUE

The relevant policy questions are: a) How can the processes of soil degradation, erosion and desertification be successfully contained, countered, delayed or stopped? b) How can the societal consequences, such as famine, distress migration and in some cases the development of conflict constellation be curbed, and the impact be reduced by early warning and rapid action (humanitarian aid)? c) How can the policy implementation be improved and corruption be curbed that the humanitarian aid reaches the most affected people fast whose survival is at stake? Two different and often mutually reinforcing policy responses and strategies to the complex linkages between desertification, drought, famine, internal displacement, cross-border migration, domestic strikes, clashes, revolts and trans-border low-level violent conflict may be distinguished:

a) *Reactive Security Policy that deals with the manifold consequences by a*rapid disaster response by the national and international humanitarian community dealing with drought, famine, migration and conflicts by enhancing the coping capacity for domestic and trans-border violence on behalf of the police and in the worst case by the armed forces.
b) *Proactive Security Policy* that addresses the causes of desertification and drought and food insecurity within the framework of international and national environmental policy by combining the efforts of (i) *Desertification* (UNCCD regime), (ii) of *Climate Change* (UNFCCC regime using the flexible Kyoto mechanisms, especially the CDM); (iii) *Reproductive Health* (UNPF); (iv) *Improved Water Conservation*, *Harvesting and Management* (efforts by FAO, UNDP, UNEP, UNESCO), (v) *Sustainable Agriculture*: (FAO, WFP, IFAD); and (vi) *Urbanisation* (Habitat).

While the task of the short-term, event triggered response is to cope with the specific impact, and thus to counter developments that may result in domestic violence, the task of the longer-term oriented proactive security strategy is to reduce the costs and impact of drought and its potentially destabilising societal consequences by early warning of famine, migration and conflict. This requires an early recognition of the security relevant environmental challenges, and a continued national and international agenda setting. However, the perception of the urgency of these slow-onset challenges of desertification and its consequences (drought and famine) depends on the mindset and the worldview of the observer, i.e. of the political elite, and of the success of the environmental agencies to get on the agenda of the key national and international decision-makers and policy institutions.

EARLY RECOGNITION AND LONG-TERM MONITORING AS AN ENVIRONMENTAL SECURITY TASK

The tools for these two policy strategies in coping with desertification, drought and famine and its possible societal consequences differ. With regard to enhancing the effectiveness of reactive measures to cope with drought, early warning systems that deal with natural hazards have become increasingly relevant such as GIEWS (Global Information Early Warning System on Food and Agriculture of FAO), and the Famine Early Warning System (FEWS) operated by the U.S. Geological Service with the support of the National Oceanic and Atmospheric Administration (NOAA).

Early Warning of Disasters

The focus of the early warning activities with regard to disasters has been primarily on technical systems to recognise and – to the extent possible – to predict increased seismic activities (earthquake, volcanic eruption, tsunami), as well as hydro-meteorological hazards and disasters (hurricane, flood, drought, fire) and biological and health hazards (infectious diseases, epidemics). According to J. C. Scott (2003) the goals of these efforts have been: "to empower individuals and communities, threatened by natural or similar hazards, to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life and damage to property, or to fragile environments". In the UN-framework, two early warning conferences in Potsdam (1998) and in Bonn (2003) have focused exclusively on technical systems and policies for early warning of natural hazards and disasters.[38] This is also a goal of the United Nations Strategy for Disaster Reduction (UNISDR)[39] and of its Working Group on Early Warning, chaired by UNEP, that focuses on the analysis of trends of hazards and early warnings to establish progress made and present gaps in this field.[40]

Early Warning of Conflicts

Completely unrelated to the debate on early warning of natural disasters has been an intensive debate in the policy-oriented social sciences on early warning efforts and indicators for national and international conflicts for the global level (UN, UNDP, UNEP, UNISDR) and the regional level of the European Union focusing on social and economic,

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[38] See EWC2 at:
http://www.ewc2.org/upload/news/Press%20Release%2016%20October%20revised%20FINAL.doc

[39] See the UNISDR website at: http://www.unisdr.org/

[40] See at:<http://www.unisdr.org/task-force/eng/about_isdr/tf-working-groups2-eng.htm >.

ethno-religious crisis, urban violence, disputes on access to water and food, hunger riots, civil wars, disputes on mass migration and on scarce resources. According to Swisspeace (FAST) the task of these efforts has been: "to recognize crucial political developments in the countries monitored in a timely manner, thus enabling decision makers to take measures to prevent violent escalation of conflicts or at least to attenuate their consequences. … to provide a database [on] the political situation, conflict and cooperation … to forecast … developments".[41] Within the United Nations, several institutions, departments and agencies have addressed the problem of an early warning of conflicts: the UN Security Council, the Secretary General (Annan 2001, 2002), the departments of political (DPA) and peacekeeping affairs (DPKA) but also OCHA (Office for the Coordination of Human Affairs). Efforts for conflict prevention has also been added to the agenda of UNHCR, IOM, UNICEF, FAO, WHO, and of the World Bank.Within the European Union, a separate *Göteborg process* has been launched by the European Councils in Helsinki (1999), Feira (2000), Nice (2000), Göteborg (2001), Barcelona (2002), and Thessaloniki (2003) that calls for an integration of considerations of conflict prevention into regional and country-specific policies of the European Union. Thus, conflict prevention has become a major declared goal of the DG Relex but also of the DG Development (Brauch/ Selim/ Liotta, 2003).

Early Warning of Disasters and Conflicts in the European Union

Within the EU, the focus is on two processes to enhance early warning of hazards, within the *Cardiff process* to include environmental concerns into all sectoral policies, and the so-called *Göteborg process* to include conflict prevention goals in all regional foreign policies. In June 2003, at the European Council in Thessaloniki, a "European Diplomacy on Environment and Sustainable Development" was adopted and a network of Foreign Ministry experts on environment and security was set up.

The EU Council document (10342/03 of 10 June 2003) noted that "poverty is linked with the natural resources and that security in its broad meaning is intrinsically linked with the opportunities for economic, social and environmentally sustainable development". The Council document listed six reasons for linkages between environment and security at both levels:

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[41] FAST.

- Scarce resources may represent a potential for conflict. The social and demographic pressures in countries can intensify the impacts on the environment and may provoke migratory waves due to the inadequacy of natural resources.
- Wars and conflicts effect the environment in a way that transcends national borders and many have repercussions for a much wider region.
- Environmentally destroyed or degraded areas after extreme weather conditions, wars and conflicts set back economic and social development and worsen the building up of peace and stability in the respective region.
- Poverty and the marginalisation both of groups within countries of countries themselves also represent a potential conflict risk.
- The reduction of transboundary pollution and the protection of shared natural resources can represent low profile policy issues between neighbouring countries, upon which a wider cooperation can be built.
- Sustainable development issues and the management of shared resources should be examined as being part of the various peace treaties, cooperation declarations and other agreements produced by bilateral and multilateral diplomatic efforts.

It was agreed that at the policy level the network will: “address the link between environment and security by ensuring that environmental factors are fully addressed in conflict prevention activities as well as in post-conflict reconstruction ... [to identify] priorities for more concerted action”.

Global Monitoring for Environment and Security (GMES)

In 1998 at Baveno (Italy) the European Commission and the European Space Agency (ESA) formulated the goals for their joint GMES-Initiative that is planned to become operational by 2008. The GMES Action Plan's Initial Period (2002-2003) was to prepare proposals for the Implementation Period (2004-2008) for the establishment of a European capacity for Global Monitoring for Environment and Security by 2008. Its Initial Period consists in two activities:

- **Delivering Information and Services and Learning.** These activities include thematic projects and the consolidation phase of the ESA GMES Service Element -GSE. Two of the GMES EC thematic projects focused on Land cover change in Europe and on desertification in the Mediterranean (LADAMER: J. Hill, Germany).
- **Assessments and Recommendations.** The purpose of the cross-cutting assessment studies to develop and assemble the documentation and expertise on which to base proposals to promote a European capacity for global monitoring of environment and security. As the work progresses, results will be discussed in GMES Forum and with GSC Working Groups.

The Implementation Period will initiate the development of the required infrastructure and organisational set up towards the establishment of a European capacity for GMES. The main results from that period of activities will include proposals for: a) improvements on infrastructures, services and knowledge; b) adjustments needed to the current activities of monitoring infrastructures, of data services, and of GMES related research and development; c) legal, institutional and funding arrangements.[42]

Upon its establishment by 2008, GMES could become an important tool for early warning of disasters and also of conflicts. During 2003 and 2003, the GMES working group on security reviewed the EU policies of conflict prevention and crisis management and concluded that GMES could support activities to address natural and technological risks in Europe, humanitarian aid and international cooperation and conflict prevention by monitoring the compliance with treaties. Potential users of the data to be

[42] For details see at: <http://www.gmes.info/what_is/index.html >.

provided by GMES could be organisations in areas of civil protection in Europe to manage natural and technological risks, European institutions, and international organisations, NGOs in humanitarian and development aid, as well as civilian crisis management outside Europe. Among its early warning tasks would be to develop forecasting tools for natural disasters, methodologies, alert tools for rapid onset disasters (storms, floods), and a contribution to conflict prevention efforts.

The Earth Summit Project

A supplementary project was launched at the G-8 meeting in Evian (2003) that has resulted in the Earth Observation Summit (EOS) Project. The First EOS occurred on 31 July 2003 in Washington, D.C., at the State Department. The goal was: a) to promote the development of a comprehensive, coordinated, and sustained Earth observation system or systems among governments and the international community to understand and address global environmental and economic challenges, and b) to begin a process to develop a conceptual framework and implementation plan for building this comprehensive, coordinated, and sustained Earth Observation System or systems.[43]

Both the European GMES and the global Earth Observation Summit process can contribute to supply data for early warning of drought but also of longer-term land-cover changes that can instigate both short-term reactive and longer-term proactive measures against desertification and drought.

Mainstreaming Both Early Warning Communities in Science and Policy

Given these parallel, and often unrelated efforts, there is a need to look for synergies between early warning efforts for natural disasters and conflicts and for initiatives to mainstream three separate technical and political efforts of a) climate change and desertification and b) disaster adaptation and mitigation (drought and famine) with c) pro-active policies aiming at conflict prevention and avoidance.

Art. 6 of the Amsterdam Treaty of the EU requires that environmental considerations must be integrated in all EU policies. With the

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[43] For details see at: < http://www.earthobservationsummit.gov/>.

so-called *Cardiff Process* that was adopted by the European Council in Cardiff (1998) a policy process was launched to implement this treaty provision by integrating environmental considerations into sectoral and regional EU policies, e.g. for:

- *Climate Change and desertification*: Long-term oriented effective mitigation and adaptation efforts may influence, counter and slow down trends towards an increase in extreme weather events and of the impact on projected increases and intensification of hydro-meteorological hazards and disasters. The key actors, agenda-setting and implementing institutions are the UNFCCC and the UNCCD secretariats in Bonn, the IPCC, and within the European Commission, the DGs for Research and Environment.
- *Disaster Response and Prevention*: Mitigation and adaptation efforts may contribute to reduce "environmental" and "societal vulnerability". The key actors, agenda-setting and implementing institutions are among others the IBRD, UNDP, UNEP, ISDR, as well within the European Commission its DG Research and DG Environment dealing with Civil Protection.

Within the European Commission the DG Environment has the responsibility for climate change, desertification and civil protection (disaster response and preparedness). To mainstream both activities and to achieve synergies among them has been a goal of a new of a dialogue project by the UN's International Strategy for Disaster Reduction (ISDR) in Geneva.

My argument is that in the medium term these two separate policy efforts launched by the European Council should be mainstreamed and synergies among efforts for adaptation and mitigation to climate change and disaster reduction as well as conflict prevention and conflict avoidance should be aimed at. So far both considerations have been included as separate policy items, e.g. in the European Union's policy documents dealing with the Euro-Mediterranean Barcelona process, e.g. in the Valencia Plan of Action of April 2002 and of the Athens Declaration of July 2002 of the Euro-Mediterranean environment ministers. A mainstreaming would require a closer cooperation between the DG Environment and DG Relex with the relevant institutions of the Council dealing with foreign and security policy. Once GMES will be operational by 2008, it can make significant contributions to both climate change and desertification, for disaster adaptation and mitigation and for conflict prevention and avoidance.

There are several advantages of linking early warning of disasters and conflicts because successful early warning of hazards will also mitigate conflicts, and successful early warning of conflicts will reduce the vulnerability to hazards. A three-fold mainstreaming of early warning efforts is needed: a) on the *vertical* level between the global, regional, national and local approaches, b) on the *horizontal* level between disaster reduction and conflict prevention, and c) among *actors*, i.e. between the political and scientific community. Humanitarian organisations and their sponsors would benefit from such a mainstreaming because they address in their activities both challenges: *disasters* and *conflicts*.To mainstream both early warning activities we need: a) systematic knowledge on interactions among fatal outcomes and societal consequences, b) analyses on the commonalities of technical forecasts of hazards and political assessments of conflicts on policy processes of warning, analyses and policy responses by IGOs and governments, c) assessments of the potential of remote sensing techniques and satellite systems for dual early warning tasks of hazards and conflicts, d) comparable case studies on the integration of different technical early warning systems, e) comparable case studies on cooperation of government agencies and IGO offices on early warning for disaster reduction as well as conflict prevention and crisis management activities, f) comparable case studies on success ("best cases") and failure of early warning of natural disasters and of crises and conflicts. This requires intensive discussions and systematic cooperation among both communities.[44]

[44] These ideas were developed first in my talks at the Third GMES Forum in Athens in June 2003, at the Second Early Warning conference in Bonn, and during a conference in May 2004 in The Hague. All talks may be accessed at: < http://www.afes-press.de/html/download_hgb.html >.

[45] See on GMOSS at: < http://gmoss.jrc.cec.eu.int/ > and on the AFES-PRESS activities within GMOSS at:
< http://www.afes-press.de/html/download_gmoss.html >.

COMBATING DESERTIFICATION AND AVOIDING CONFLICT

There exists a threefold task: a) to focus on the causes and triggers of global environmental change as well as on local environmental scarcity, degradation and stress, and b) on its fatal outcomes and potentially violent consequences, and c) to mainstream research efforts and policy activities on environmental hazards and for conflict prevention. There is no simple strategy to counter and combat desertification and its fatal outcomes but a complex set of strategic components is required by different national and international, societal and economic actors.

Desertification and Drought: A New Security Challenge!

It has been argued in this chapter that desertification, drought, famine and hunger riots must be analysed as part of a causal chain linking Global Environmental Change (GEC) and its fatal outcomes.

Desertification and drought are no hard security threats. They pose no military threats, nor do they create or legitimate new military missions. They can neither be solved from a Hobbesian security perspective, nor from a Cornucopian environmental standpoint. They require a long-term cooperation among scientists and practitioners using both traditional, local and advanced technological knowledge. They also require a broad, long-term, pro-active local capacity-building.

Desertification and drought are emerging soft security challenges that may cause environmental and social vulnerabilities and they may trigger under specific global, national, regional and local conditions for violent societal consequences, e.g. general strikes and hunger revolts that may in some extreme cases challenge regime stability and the survival of governments.

In this chapter, desertification and drought have been conceptualised as environmental security challenges, vulnerabilities and risks, as well as human security challenges for whom not the state but the individual, family, village, tribe, ethnic group or a region are major referents. Very often the value at risk has been human survival and the livelihood of the poor with low resilience. The cause of the challenge has been nature or the GEC, the nation states and in some cases the globalisation process.Desertification and drought have also become a food security challenge, while drought and famine poses a health security challenge. Drought, famine as well as drought- and famine-induced migration pose livelihood security challenges, vulnerabilities and risks. Drought, famine and migration may trigger violent social consequences and thus become: social, national and international security challenges, risks and only in very extreme cases military threats.

Research Needs: Desertification - Drought - Famine - Migration – Conflicts

It has been argued above that much knowledge is available on individual factors of GEC and individual fatal outcomes but little on interactions and linkages between global environmental change and fatal outcomes. However, systematic social science research on linkages among the fatal outcomes and between natural hazards and its potentially violent consequences so far hardly exists due to disciplinary constraints. There is a lack of multi-, trans- and interdisciplinary research integration within the global change community, e.g. between desertification and climate change specialists, and among specialists on six the factors making up the survival hexagon.

Desertification and Drought Mitigation: Some Policy Conclusions

Thus, combating desertification and drought is not only a major technical environmental task – in the wider sense the security concept has been introduced above – it has also become a non-military human and environmental, food, health and livelihood security task for agricultural and environment policy.

Coping with drought and famine are major preoccupations of OCHA, ECHO, FAO, WFP, WHO, and of many other international governmental and non-governmental organisations. Coping with environmentally- and disaster-induced migration is the main focus of UNHCR and IOM, and trying to resolve, prevent and avoid violent conflicts has become a joint task of international institutions, including the EU and NATO and their dialogue and cooperation partners in the Mediterranean.

Combating desertification is a major environmental, development but also a new cooperative security task for the EU and NATO in

Mediterranean. The Valencia workshop by bringing together technical specialists from all NATO and Mediterranean dialogue partner countries has contributed to recognition of the soft security dimension of desertification, drought and famine.

Beyond scientific dialogue and research more pro-active policies by states and international organisations in the Mediterranean may be needed addressing the manifold causes of desertification, among them population growth (South), market forces (North) and climate change impacts (on either side).

Policy Conclusions and Recommendations

To mainstream both early warning activities on natural hazards and on conflicts more systematic knowledge on interactions among fatal outcomes and societal consequences is needed, including analyses on the commonalities of technical forecasts of hazards and political assessments of conflicts, on policy processes of warning, analysis and policy responses by IGOs and governments. In this regard the potential of remote sensing techniques and satellite systems for dual early warning tasks must be assessed for the Mediterranean region.

Comparative case studies on the integration of different technical early warning systems (e.g. on crops, drought, migration, crises and conflicts in the Nile Basin, Sahel, Southern Africa) could become a helpful instrument, including studies on the cooperation of government agencies with offices of international organisations on early warning for disaster reduction and response as well as conflict prevention and crisis management activities. Finally, comparable case studies may be helpful on success stories ("best cases") but also on failures of early warning of natural disasters and on crises and conflicts. This requires intensive discussions and systematic cooperation between both communities in science and politics.

Combating Desertification and Avoiding Violence: Tasks for NATO and EU

Both NATO and the EU in their respective Mediterranean activities, i.e. in NATO's political and scientific Mediterranean dialogue with 7 partners, and in the EU's Euro-Mediterranean partnership in the framework of the Barcelona process have different but complementary tasks. As part of its scientific activities, NATO's Science Division and CCMS programme has provided an opportunity for a Trans-Mediterranean discussion on the "security dimensions" of the desertification challenge, and thus has put "desertification and drought" on both the scientific and political agenda for its Mediterranean dialogue.

The European Union has a broader political mandate and also financial resources to add the security dimension of desertification to the agenda of its new foreign policy network on environment and sustainable development, on its own Barcelona process, and as a research topic in the context of its sixth Framework Programme on Research. "Desertification as a new security challenge" has already been added to a scientific reconceptualisation of security in the framework of a new EU-sponsored network of excellence on security (GMOSS).[45] Desertification and drought are also new problems that should be addressed both in the framework of GMES and it may be added on the agenda of the global Earth Observation Summit process.

The mainstreaming of early warning activities focusing on both natural hazards and conflicts has been discussed as an emerging issue at the second Early Warning Conference in Bonn (2003) but the task to bring both conceptual and operational communities together remains a longer-term goal NATO may consider as part of its agenda-setting scientific activities for the years to come.

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THE POSEIDON PRAIRIE

Desertification, Environmental Stress, and the Euro-Mediterranean Space

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ABSTRACT

This chapter assesses the implications of desertification in the Euro-Mediterranean space. In doing so, assessments of environmental and human security aspects significant to this geographic space help broaden the geostrategic significance of the region. The chapter argues that there are crucial differences between threats and vulnerabilities, distinguishes between the two, and suggests relevant policy applications for Euro-Mediterranean states. Some of these vulnerability aspects, including desertification, present long-term challenges to stability and security. The analysis includes a review of theoretical models that have been proposed in research. Specifically, this review addresses what have been argued as "trigger mechanisms" that can unleash violent conflict, create socio-economic disparity, and induce long-term insecurity. In lieu of an overarching conclusion, a number of suggestions are included for both future research and possible policy solutions.

"Our scientific ability to predict
environmental consequences from anthropogenic-induced change
is somewhere behind our ability
to predict the weather next week."
W. C. King
Understanding Environmental Security: A Military Perspective[1]

***Desertification in the Mediterranean Region*: *a Security Issue,* 87–108.**
William G. Kepner, Jose L. Rubio, David A. Mouat & Fausto Pedrazzini, eds.

Desertification as a security issue is not yet widely recognized—or understood. Perhaps part of this recognition delay stems from the general definition that the United Nations has offered for desertification: "*land degradation* in arid, semiarid, and dry subhumid areas of the world resulting from a combination of factors including climatic variations and human activities". [2] While this definition distinguishes that desertification study and action concern themselves with areas of land suffering from degradation, rather than those areas turning to desert, this identity does not perhaps address the larger interrelationship among regional ecologies and the collective biomass. Among the maritime fauna of the Mediterranean Sea, for example, is a species commonly known as "Poseidon Prairie," which collectively supports and helps sustain the underwater environment. Yet the "Poseidon Prairie" is itself subject to the degradations of climatic variations and human activities just as land degradation is in the broader definition of desertification. The destruction, or the sluggish degradation, of fauna will have far wider impact than the disappearance of certain species. In brief, there is a wide connectivity among climatic variations, human activities, and environmental impacts. And, however slowly, there is emerging an acknowledgment of these relationships to security.

This emerging recognition, nonetheless, has a relatively brief history. In November 1995, the foreign ministers of twenty-seven European and Mediterranean countries agreed—through the support for three "baskets" (political, economic, and cultural)—on the need to develop long-term partnership building measures in the region, as well as to focus on global stability and the common (mis)perceptions that contribute to it. This agreement and the subsequent debate and discussion that have arisen since that first meeting are collectively known as the Barcelona Process.

While recent European Union documents that periodically review the state of the Barcelona Process and the Euro-Mediterranean partnership do not explicitly reference either environmental or human security, policy makers do seem increasingly to recognize that there is a fundamental linkage between these issues and the long-term future of the region. [3] As one outcome, identifying and acting on problems of environmental degradation and resource scarcity may come to be a common feature of future security policy. Yet as the above epigraph to this essay illustrates, the difficulty in predicting—l*et al*one the ability to determine with *complete certainty*—hard "trigger" events that will affect peace and human rights and cause conflict will continue for some time.

Doubtless, environmental and human security remain both evolving and contested concepts. Yet the *vulnerability* aspects that these security issues involve present serious long-term challenges to the success and stability of the future Euro-Mediterranean. This chapter, aside from offering a general approach to the meaning of environmental security, argues that there are crucial differences between *threats* and *vulnerabilities,* distinguishes between the two, and suggests relevant policy applications. The analysis includes a review of theoretical models that have been proposed in recent research and considers their relevance to the region. Specifically, this review addresses what have been argued as "trigger mechanisms" that can unleash violent conflict, create socio-economic disparity, and induce long-term insecurity. Finally, a number of policy issues relevant to future research are considered as bases for stabilizing and support foundations during periods of future change and potential crisis.

Policy makers should recognize that there is a fundamental linkage between resource issues and security, and that these issues and the long-term future of the region will negatively degrade unless some effort is made to reverse the tide. [4] Identifying and acting on problems of environmental degradation and resource scarcity, in the best possible world, ought to be a common feature of future security policy. Above all, it remains crucial to recognize that such issues cannot be separated from larger regional co-operative and competitive interests, which also cannot be considered in isolation from each other.

DEFINING ENVIRONMENTAL SECURITY

Moving from the specific aspects of geographic and geopolitical challenges in the Euro-Mediterranean that specific other chapters in this work detail, the intent here is to consider how theoretical approaches to "non-traditional" (or non-military) security issues have been considered elsewhere in the recent past. To do this correctly requires recognizing some fundamental shifts in security definition—particularly with the emergence of human and environmental security themes in the 1990s.

In terms of precise categorization, there are critical differences between human and environmental security. In the broadest sense, environmental security considers issues of environmental degradation, deprivation, and resource scarcity; by contrast, human security examines the impact of systems and processes on the individual, while recognizing basic concerns for human life and valuing human dignity. Yet as numerous examples illustrate, complex interactions within various environments often place stress on the security of the individual. Thus, environmental and human security often co-exist in a complicated interdependence best conceptually considered as “extended security”.

Policy makers would be wise to recognize this conceptual approach.[5] Yet for research to be relevant to policy makers, it should almost always contextualize significance within a specific human- and regional-oriented perspective. To be blunt, there is a specific and pragmatic reason for emphasizing these issues in terms of security: doing so both makes the topic accessible for decision makers and provides a basis for determining present and future policy. Ole Wæver, one of the earlier influences (along with Barry Buzan) in promulgating the “new security agenda” reflects a certain skepticism, nonetheless, about the ability to influence policy through reframing the understanding of security:

A security issue demands urgent treatment: it is treated in terms of threat/ defence, where the threat is external to ourselves and the defence often a technical fix… traditionally the state gets a strong say when something is about security. To turn new issues (such as the environment) into “security” issues might therefore mean a short time gain of attention, but comes at a long-term price of less democracy, more technocracy, more state and a metaphorical militarisation [sic] of issues. For this reason, environmental activists and not least environmental intellectuals who originally were attracted to the idea of “environmental security” have largely stepped down…Security is about survival…The invocation of security has been the key to legitimizing the use of force, and more generally opening the way for the state to mobilize or to take special force…Security is the move that takes politics beyond the established rules of the game.” [6]

There are, however, any number of overextending assumptions in the above reference. Above all is the assumption that security is an extreme term that can only be couched in terms of threat, and that the state—as political monolith—can only respond with the use of force. Security is far richer in contextual meaning than such a stratified identity seems to allow.

Security is a basis for both policy *response* and long-term *planning.* Further, the use of force—particularly military force—is often an ineffectual and irrelevant response to the “new security agenda.” Thus, the argument that “environmental security” is simply a mask for military intervention is an argument that is, at best, thin. What *is* true is that the understandings of, and definitions for, environmental security range so broadly that its meaning takes on something for everyone—and perhaps, ultimately, nothing for no one.

For the specific relevance of the term "environmental security" applied to the significance of desertification in the Euro-Mediterranean, the broadest relevant definition should be, and should remain, an understanding that environmental security centers on a focus that seeks the best effective response to changing environmental conditions that have the potential to reduce stability, affect peaceful relationships, and—if left unchecked—contribute to the outbreak of conflict. Perhaps ironically, the best overall definition for environmental security relevant to the Euro-Mediterranean space was written decades ago, when Norman Myers argued that

National security is not just about fighting forces and weaponry. It relates to watersheds, croplands, forests, genetic resources, climate and other factors that rarely figure in the minds of military experts and political leaders, but increasingly deserve, in their collectivity, to rank alongside military approaches as crucial in a nation's security. [7]

In contrast to Wæver's suspicious pessimism regarding the true political motives for the environmental security agenda, and in support of Myers' above ideas on the need to rethink—and re-conceptualize—security, one would hope that both military and political leaders will come to widely recognize the validity of environmental security for strategy and policy initiatives. Based on the tensions, disagreements, and uncertainties regarding desertification in the Euro-Mediterranean, it is not clear—and, sadly, not likely—that this recognition will forestall some potentially disastrous outcomes in the region.

THREAT AND VULNERABILITY: THE DIFFERENCE BETWEEN THEM AND WHAT IT MEANS FOR DESERTIFICATION

In the definitions offered above, much of the distinction centered on the best approach to dealing with environmental *threats.* Even those, such as Wæver, who first promulgated the idea of environmental security and then backed away, seemed to have done so because of the implication that security contextualization must be couched solely in terms of threat response with use of (almost always, military) force. Few of the definitions, with the possible exception of Myers, recognize that *vulnerability* can also be a key feature of the security calculus. Although few policy makers might immediately recognize the difference between the terms, both concepts suggest different realities.

A threat is *identifiable, often immediate, and requires an understandable response*. Military force, for example, has traditionally been sized against threats: to defend a state against external aggression, protect vital national interests, and enhance state security. A threat, then, is either *clearly visible or commonly acknowledged.*

A vulnerability is often only *an indicator, often not clearly identifiable, often linked to a complex interdependence among related issues, and does not always suggest a correct or even adequate response.* While disease, hunger, unemployment, crime, social conflict, terrorism, narco-trafficking, political repression, and environmental hazards are at least somewhat related issues and do impact the security of states and individuals, the best response to these related issues, in terms of security, is not at all clear. Further, a vulnerability (unlike a threat) is *not clearly perceived, often not well understood, and almost always a source of contention among conflicting views.*

Thus, the *time* element in the perception of vulnerability can also further confound the problem—and make vulnerabilities far more controversial and far less pressing than the clear and present dangers of threats. Extreme vulnerability can arise from living under conditions of severe economic depravation, to victims of natural disasters, and to those who are caught in the midst of war and internal conflicts. The situation, to be blunt, is one not of sustainability but of rescue.

But there are also cases of long-term vulnerability in which the best response is uncertain. Given this uncertainty, the frequent—and classic—mistake of the decision maker is to respond with the "gut reaction." Thus, the intuitive response to situations of clear ambiguity is, classically, to *do nothing at all.* The more appropriate response is to take an adaptive posture; to avoid the impulse to act purely on instinct; and to recognize what variables, indicators, and analogies from past examples might best inform the basis of action. Yet environmental and human security, since they are contentious issues, often fall victim to the *do nothing* response because of their vulnerability-based conditions in which the clearly identifiable cause and the desired prevented effect are often ambiguous.

What are the implications for desertification in the Euro-Mediterranean? Essentially, a number of vulnerability issues, if left unchecked over time, can take on significance that could easily impact effective governance and *potentially* lead to conflict. To be specific, vulnerabilities, if left unchecked over time, *become* threats.

REVIEW OF ENVIRONMENTAL SECURITY AND STABILITY MODELS

A review of recent research suggests that some theoretical models have attempted, at least, to be all encompassing in their explanation for environmental performance as well as offering causality for potential conflict and stability impact.

This brief review will consider some of these predictive models, to include interdependent factors that are "trigger mechanisms" that can unleash violent conflict, create socio-economic disparity, and induce long-term insecurity. [8] The application of these particular arguments for geo-specific research—such as how water scarcity, desertification, human population flows, and other related (and interdependent) security issues in the Euro-Mediterranean affect one another—has not yet reached a point of precise refinement.

Environmental Performance and Human Security Indicators

Research conducted at the U.S. Naval War College, which bounded its own focus to the extent of the European Command's regional area of responsibilities—to include much of MENA (Mediterranean, Europe, and North Africa)—provides a sound basis from which to consider factors relevant to human security, environmental change, and regional application.[9] As S. R. Hearne argues, understanding and extrapolating from environmental indicators can prove effective in both providing feedback on, and assessing progress made, towards:

•Reporting on the state of the environment per national law or other agreements;
•Raising environmental issues onto the political agenda to promote further debate;
•Supporting policy development to address priority environmental concerns;
•Supporting efforts to address environmental problems during budget formulation;
•Measuring environmental performance and the success of policy responses;
•Identifying trends by major sectors, such as energy, agriculture, transport, industry;
•Establishing environmental targets at the sectoral and sub-national levels;

•Providing early warning to prevent environmental damage;
•Measuring progress towards sustainable development;
•Facilitating national, regional, and international environmental planning;
•Prioritizing regional intervention and engagement activities; and
•Communicating progress to the public and national and international institutions. [10]

Direct and indirect pressures therefore affect sustainable development over the long term and can potentially induce human security crises. Both the OECD and the European Union have developed frameworks intended to illustrate how states and communities might best respond to events and to develop alternative policies or behavioral responses. [11] Specifically, the OECD "Pressure State Response Model" (or PSR) framework illustrates in simple context the often complex causal relationships induced by environmental change and human societal response to or effect from such change. [12] It seems also worth noting that the World Bank in its own assessments has largely accepted the PSR framework in linking environmental problems to developing program objectives. [13]

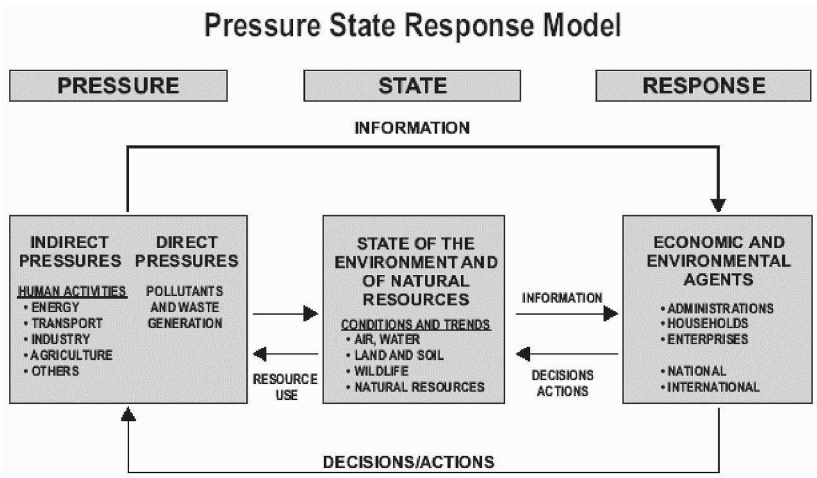


Figure 1. The Pressure State Response Model. Source: OECD. Towards Sustainable Development-Environmental Indicators. 1998

Sustainability Indices

Moving from an overall descriptive assessment of the nature of environmental driving forces and pressures on particular states, there have been a number of arguments for a single index of sustainable development from which to best assess and respond to situations of human security distress and environmental change. Perhaps the best known of these indices is the United Nations Human Development Index (HDI), which correlates three specific factors that suggest the normative dimension of social sustainability—life expectancy, education, and Gross Domestic Product (GDP). While acknowledging that the widely referenced HDI is itself perhaps insensitive to some aspects of human security, the United Nations' own Commission on Sustainable Development has noted that there may indeed need to be some caution exercised regarding use of the HDI as an exclusive influence for national policy making. [14]

As an alternative index, one of the more intriguing frameworks that seeks to encompass a richer display of factors and influences than the HDI is the European Commission's Joint Research Centre example of the "Dashboard of Sustainability." So named because it is meant to metaphorically represent the clusters of indicators displayed on the dials and gauges of a complex instrumentation panel (or a car dashboard), the framework means to monitor environmental quality, provide system feedback, reflect economic performance, and assess institutional factors. [15]

Notably, the Commission on Sustainable Development criticized the original "Dashboard" framework as simplistic and basic, and lacking in sufficient detail to offer true merit as a policy tool. [16] A subsequent revision of this framework, nonetheless, appears to have incorporated this criticism, as the following example for the nation of Georgia attempts to demonstrate:[17]

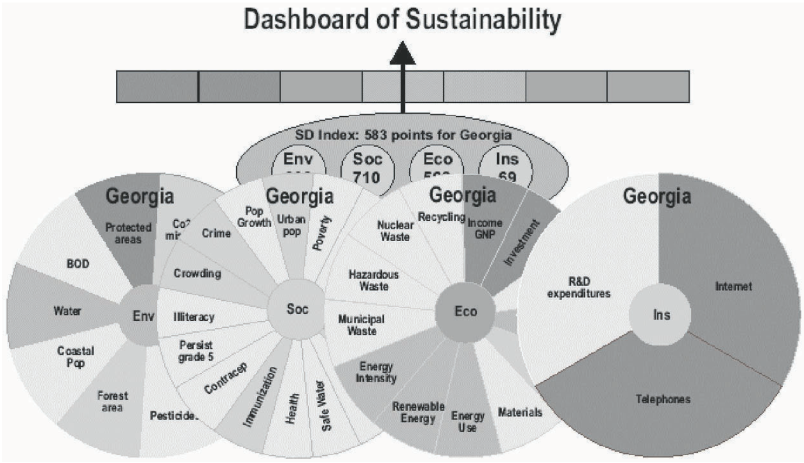


Figure 2. Dashboard of Sustainability. Source: www.iisd.org/cgsdi/dashboard.htm

Similar indices are available for over one hundred nations. Performance indicators rely on a seven-color coded system—dark red for worst outcome, dark green for best case—and specific policy performance in each dimension is also scored using a point system ranging from 0 (dark red) to 1000 (dark green). Finally, the software package calculates an overall Sustainable Development Index (SDI) for each country. Thus, while the "Sustainability Dashboard" may not represent the most widely accepted index, it does offer intriguing possibilities for geo-specific comparisons for states and communities.

An alternative sustainability index is the Environmental Sustainability Index (ESI). A collaborative effort between the World Economic Forum's Global Leaders for Tomorrow (GLT) Environmental Task Force, the Yale Center for Environmental Law and Policy (YCELP), and the Columbia University Center for International Earth Science Information Network (CIESIN). [18] First released at the World Economic Forum's annual meeting in 2001, the ESI ranked 122 countries according to their specific achievements in environmental sustainability—defined as the ability to produce significant results in five core component areas: environmental systems; reducing environmental stresses; reducing human vulnerability; social and institutional capacity; and global stewardship. An illustrative example of these five component factors is portrayed below and attempts to articulate how specific states are measured for environmental sustainability.

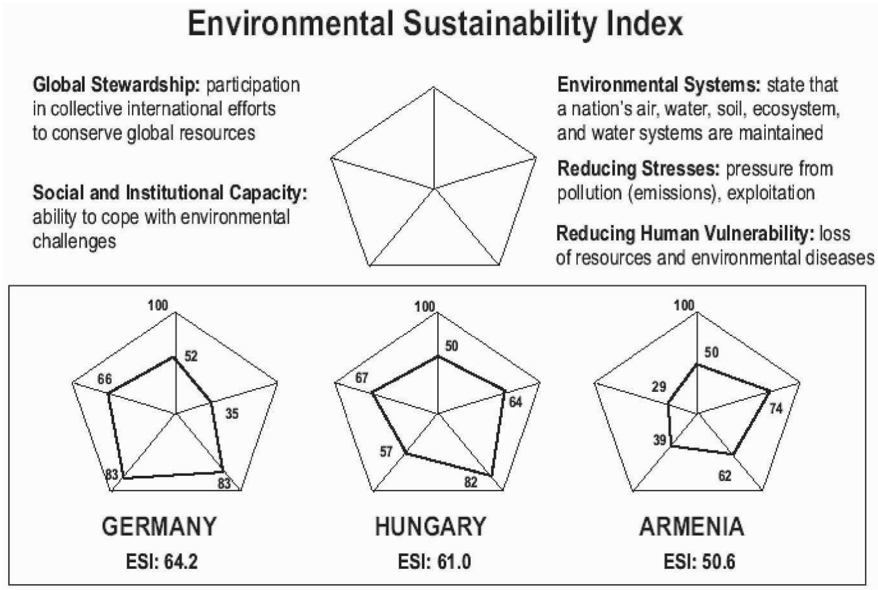
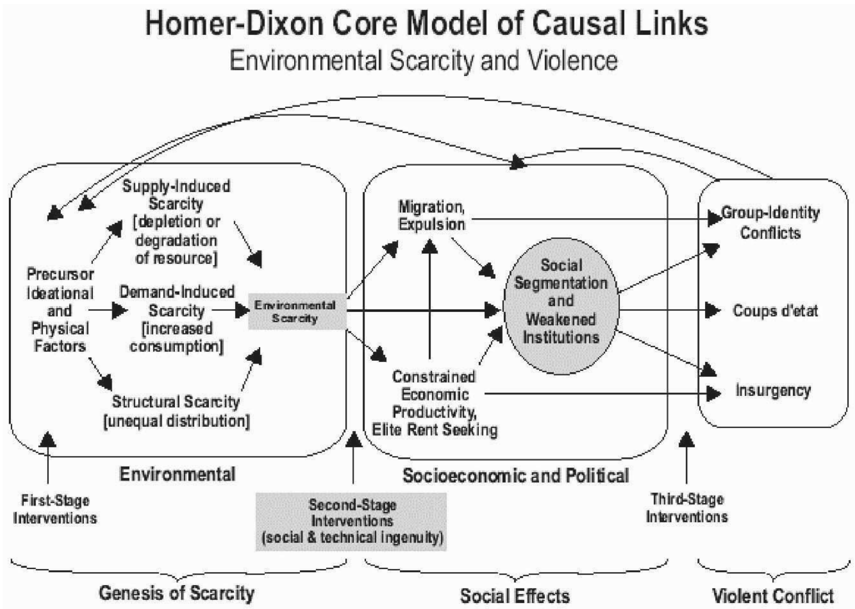


Figure 3. The Environmental Sustainability Index
Source: www.ciesin.columbia.edu/indicators/ESI/downloads.html

While some have also criticized the validity of the Environmental Sustainability Index (in which, for example, the Russian Federation was ranked 33rd while Singapore is ranked 65th overall), the ESI research team has argued that the index serves as an underpinning tool that can form a viable "watch list of countries facing potential environment-driven crises."[19]

Stability Assessment Frameworks and Causal Explanations for Conflict

The concept of state failure became a dominant theme in the 1990s—partially as a result of the journalist Robert Kaplan's piece titled "The Coming Anarchy" (which appeared in the February 1994 issue of *Atlantic Monthly*) as well as work that began at the Peace and Conflict Studies Program at the University of Toronto. The director of that program, Thomas Homer-Dixon, refined his earlier ideas in a 1999 book titled *Environment, Scarcity, and Violence.* [20] Drawing on more developed analysis than in previous research results, Homer-Dixon examined the causal links between socio-economic, political, and environmental "stressors" and proposes a "Core Model" of causal linkages. The resulting causal linkage model included feedback loops and provided for different stages for external (and internal) intervention. In contrast to earlier case studies on environmental scarcity, state failure and conflict, later research recognized that to assert environmental scarcity as *specific* explanation for conflict is difficult, at best, to prove—since scarcity itself is "always enmeshed in a web of social, political, and economic factors." [22]



Note: The term "environmental scarcity," used in the Core Model, reflects the scarcity of renewable resources, and accounts for supply-induced scarcity, demand-induced scarcity, and structural scarcity. [21] What is notable about this model's relevance to the Euro-Mediterranean is that—specifically, as concerns desertification issues—supply-induced scarcity, demand-induced scarcity, and structural scarcity are occurring simultaneously in the region as a result of larger security struggles.

Figure 4. Homer-Dixon Core Model of Causal Links.
Source: Environment, Scarcity, and Violence Adapted from Homer-Dixon, 1999

In developing this causal linkage model above, the Toronto research team employed a method of "process tracing": a step-by-step analysis of causal processes drawn from specific case studies, attempting to focus on "if" and "how" environmental scarcity contributes to violent conflict. Homer- Dixon's work suggests that environmental scarcity is mainly an indirect cause of violent conflict.

A second influential framework—which, intriguingly, was created *after* the publication of Kaplan's "Coming Anarchy" essay, and was meant as a partial response to the pessimistic assessments in Kaplan's argument—is the State Failure Task Force Phase II "Mediated Environmental Model." Claiming to be the first reported empirical large-scale study to investigate the critical factors most responsible for state collapse and failure, the State Failure Task Force was created in 1994 following a request by then–Vice President Al Gore. [23] At that time, there was a sense of increasing instability and collapse of governance in many nations of the world following the end of the Cold War.

Policy makers hoped, therefore, that research into state failure might provide indicators of early warning to facilitate suitable forms of international intervention. In response, the Central Intelligence Agency established the State Failure Task Force, to conduct a comprehensive examination of why certain states succeeded while others seemed to fail. Research was conducted in a series of phases; for the purposes of this chapter, only results from the Phase II report appear.

The task force's predictive "Mediated Environmental Model" considered aspects of Democratization, Trade Openness, Environmental Stress, Material Well-Being, Vulnerability, and Capacity as they contribute to the likelihood of state failure. Equally, a separate model based on Sub-Saharan Africa results revealed the not-surprising though disturbing indicator that partial democracies (as some of the states of the Euro-Mediterranean would prove at best to be) are at a relative risk of failure *eleven times greater* than an autocratic state under similar conditions of stress. Further, counterintuitive issues such as "infant mortality" rates took on great significance in the study, because of their broader impact on other well-being issues. Such counterintuitive issues, therefore, also constitute initial warnings of serious systemic problems.

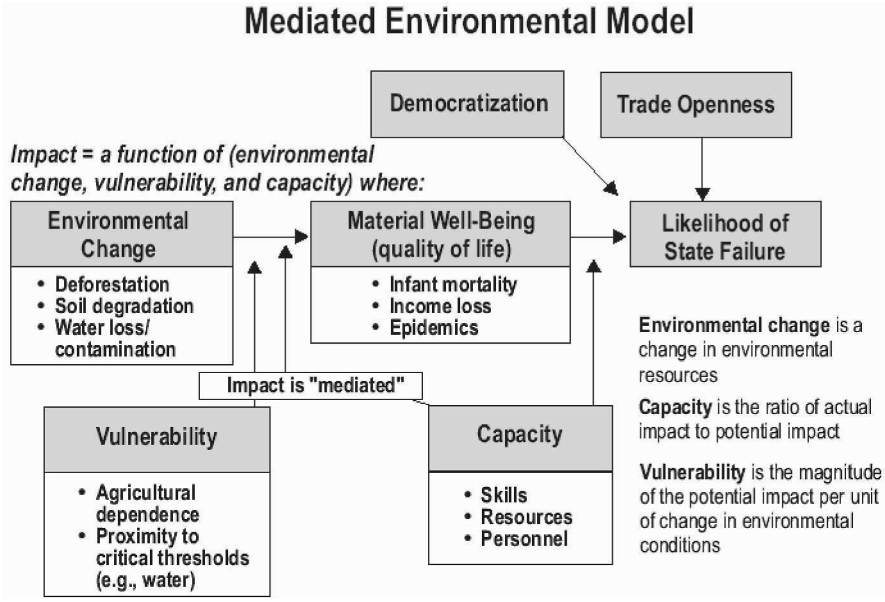


Figure 5. The Mediated Environmental Model
Source: State Failure Task Force Report: Phase II Findings, 1998

While the aim of the argument here is *not* to suggest that state failure is imminent in the Euro-Mediterranean, there are some parallels to be drawn. Specifically, desertification is part of a larger complexity linked to security.

Major findings from the Phase II State Failure research that have some significance for the Euro-Mediterranean include:

•Partial democracies are particularly vulnerable and at elevated risk of state failure;
•gradual transition to democracy will likely improve the chances for success; and
•ethnic discrimination alone may not be the most critical factor leading to conflict, as was evident in a modified global model developed for Sub-Saharan Africa.

The State Failure Project Phase II research also investigated the impact of environmental change on material well-being as a function of national resource vulnerability and a state's institutional capacity to respond to the stressors associated with environmental change. Significant findings include:

•Environmental change does not appear directly linked to state failure; rather it is part of what has already been described as a complex linkage and interaction among a number of socio-economic, political, and environmental stressors;
•to respond by the degree its resources are vulnerable to environmental shock;
•Analyses are being hampered by a lack of long-range environmental data.[24]

This last assessment is clearly evident in the Euro-Mediterranean dilemma today.

NEO-MALTHUSIANS VERSUS NEO-ECONOMISTS

Desertification, as an environmental degradation factor, is among a variety of "scarcity" issues that can aggravate state governance and fuel opposition to a state's policies. Notably, this is occurring in Central Asia today, with the rise of the Islamic Movement of Uzbekistan (IMU). There is, nonetheless, a real danger in assuming that either degradation or scarcity always leads to conflict. [25] Nils Petter Gleditsch, in particular, has been prominent in challenging these connections as certainty.

What remains valid is that such a connection, under certain circumstantial conditions, could plausibly take place. Such an outcome, given its conditionalities, alternatives, and uncertainties, is hardly something worth betting the future on, nonetheless. Often, this divergence of perspectives becomes a simple issue of optimism versus pessimism. Both Colin Kahl and Nils Petter Gleditsch have coined these contrasting views in different, though similar, terms as "Malthusians" ("or "Deprivation Hypothesists") versus "Cornucopians" (or "Neo-Economists"). [26] Stated simply, the Neo-Mathusian arguments boil down not to a contrast between the "haves" and the "have nots" but one between the "haves" and the "wants." From a less optimistic perspective, deprivation as well as demographic and environmental pressures leads to sense of difference among the disadvantaged, between what people want and need, between what people have and what they think they deserve. By contrast—even under similar conditions—Neo-economists would argue that demographic and environmental stress can be countered, and civil strife averted, if population growth (including youth bulges) does not lead to resource scarcity (from factors such as desertification and insufficient water-carrying capacity) and economic decline.

Despite their contrasting stands, nonetheless, both approaches acknowledge a distinction between short-term demographic and environmental pressures and long-term capacities. What remains unconsciously acknowledged but virtually unstated is the need to establish "Human Ecology" as a discipline, to bridge the gap between rival theories and build on strengths and insights rather than to win the argument over crucial differences of perspective.

SUGGESTIONS FOR FUTURE RESEARCH

While acknowledging that such forecasts are *not* strict predictions—but rather *projections*—from reasonable indicators of current and recent trends and effects, there can be little doubt that significant change may well occur in the Euro-Mediterranean context regarding desertification issues. Such change will directly affect the security calculus of the entire region. As such, a number of general conclusions and concerns could be raised about the shifting landscape of the Euro-Mediterranean and the critical uncertainties that will inevitably emerge, conclusions that ought to have a direct impact on finding geostrategic and policy solutions:

1. Desertification as a security issue forms part of a larger network of cultural, political, and economic linkages in the Euro-Mediterranean. To date, little multilateral agreement has been reached that will solve the wider negative consequences of collapsing "extended security," exemplified by a potential impending crisis in the region.

2. Unless significant institutional agreements are reached, there will equally be little incentive to establish or sustain early-warning and conflict prevention centers for the Euro-Mediterranean.

3. The specific relevance of the term "environmental security" to the Euro- Mediterranean should be framed as an understanding that environmental security centers on a focus that seeks the best effective response to changing environmental conditions that have the potential to reduce stability, affect peaceful relationships, and—if left unchecked—contribute to the outbreak of conflict.

4. A number of uncertain vulnerabilities must be vividly presented to policymakers as having serious long-term consequences, to include their eventual emergence as threats. Vulnerabilities, if left unchecked over time, become threats. This is clearly relevant to the Euro-Mediterranean space and the issue of desertification.

5. Military and political leaders should recognize the validity of environmental security for strategy and policy initiatives. The application of these particular arguments for geo-specific research has not reached a point of precise refinement. Models, developed to date, remain insufficient.

6. Further research must concentrate on obtaining reliable and broad indicators of environmental change measured over longer periods of time. Although recent research suggests vastly increased upswings in ecological/natural disasters in the Euro-Mediterranean, more data is required.

7. We must recognize the relevance—and the danger—of adding the term "security" to either environmental or human-centered concerns. To be blunt, there is a specific and pragmatic reason for emphasizing these issues in terms of security: doing so makes the topic accessible for decision makers and provides a basis for determining present and future policy.

8. Further research must concentrate on obtaining reliable and broad indicators of environmental change measured over longer periods of time. Solving, or at least better addressing, desertification issues in the Euro-Mediterranean may help solve socio-economic issues such as the transition to democratic, or stable, governance in each state and mitigating the causes and effects of negative transnational aspects in the region.

Ultimately, the inconclusive and sometimes contradictory results of various models and frameworks relevant to an examination of "extended security" in the Euro-Mediterranean leave us in a state of uncertain certainty. Environmental change is occurring now that clearly will affect the security calculus, but we simply do not know enough or have available data for definitive proof. Further, while we may recognize vulnerabilities, or aspects of what may be vulnerabilities, we simply do not know which will emerge as threats.

Thus, researchers who might desire a specific quantitative outcome in studying and applying focus to geo-specific regions, such as the Euro-Mediterranean space, are still unable to "bound" expected outcomes and prevent potential future negative security events. Such modeling could be inherently dangerous, however, particularly if used as the exclusive basis for foreign policy decisions to intervene or abstain in attempting to control the boundaries of a collapsing state or region. Models, driven by quantitative outcome answers, may ignore the value of qualitative process examinations that help frame more appropriate questions. Further, predictive modeling may lead as well to determining "permanent failure states": those states that, based on quantitative analysis alone, would appear to have no possibility of social, political, or economic recovery. One possible alternative to projective modeling, therefore, might include a more balanced focus on recognizing the complex interdependence of socioeconomic, environmental, and institutional factors. A recently developed framework that offers this balanced approach—simple in concept, immensely difficult in practice—is S. R. Hearne's Stability Pyramid: [27]

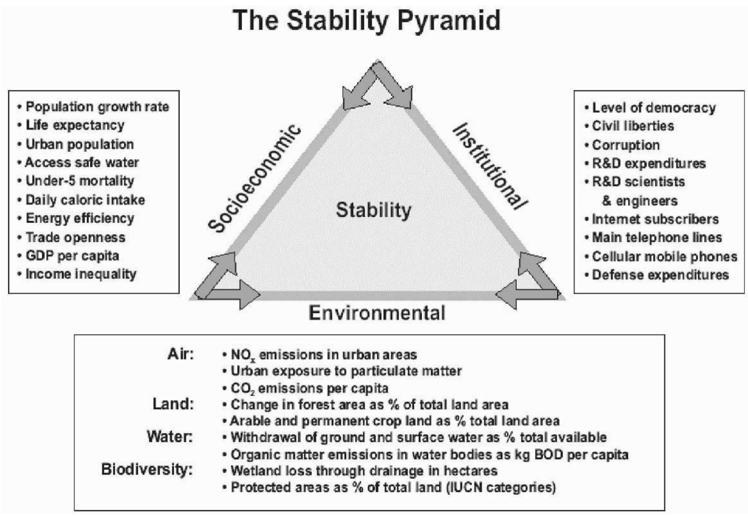


Figure 6. The Stability Pyramid
Source: S. R. Hearne, Advanced Research Project, Naval War College, 2000–2001

Hearne's Stability Pyramid may also point to a crucial missing link in the security dilemma that has characterized the 12 September world (as well as the post–Cold War world). While much discussion came about following the publication of Francis Fukuyama's essay "The End of History?" about the critical importance of democratization and (economic) liberalization, little relative weight was given to the systemic and structural importance of environmental aspects such as scarcity. Fukuyama first explicitly argued in 1989 that, with the end of the Cold War, specific nations and regions may have reached "the end of history," in which Western liberal democracy will represent the final form of human government. Admittedly, a decade later, Fukuyama recognized that he did not sufficiently account for the social, cultural, political—and military—effects of globalization, information technology, and biotechnology in making his original argument. He insisted, however, "Nothing that has happened in world politics or the global economy in the past ten years challenges, in my view, the conclusion that liberal democracy and market-oriented economies are the only viable options for modern societies." [28] Yet the crucial linkage of environment to security in some societies may only now be emerging as a recognition of equal importance and a new reality of pressing need.

Ultimately, the complexity of human interaction with and response to complex environmental influence may well lie beyond any viable or accurate modelling attempt. Admittedly, this is a contentious conclusion, but probably an honest one as well. Reasonable strategies for regional security and ecological stability in the Euro-Mediterranean thus need to balance preoccupation with rationality with the recognition that policymakers almost always lack clairvoyance, suffer from cultural blinders, and are often driven by contingency responses. These studies should further recognize reasonable alternative appraisals, the frequent lack of will and resources, and the nature of the overall desired goals of multiple players involved in any scenario. Most often, these crucial actors enter into a kind of psychological—and sometimes physical—St. Vitus' dance until exhaustion or resolution sets in. At best, we should hope for the participation of multiple decision makers and for the desire for all within the region to be involved. And as we assess the future of the Euro-Mediterranean and the impact of desertification, we know that change is *already* under way—but how, in what way, and whom this change will most directly affect remain an uncertain certainty we must consider in defining this vulnerable geography. The decisive issue remains clear: how well we address the complex inter-dynamics of climatic variation, human activities, and environmental impact will determine the fate of the “Poseidon Prairie” as well as the entire region.

NOTES

1 W. Chris King, Colonel, United States Army, Chair of the Department of Geography and Environmental Engineering, United States Military Academy. Dr. King wrote this unpublished study as an advanced research product while serving as a West Point Fellow at the U.S. Naval War College, during the academic year, 1999–2000.

2 Adapted from conference notification, “Desertification in the Mediterranean Region: A Security Issue,” NATO —CCMS and Science Committee Workshop on Desertification in the Mediterranean Region. A Security Issue. http://www.epa.gov/nerlesd1/land-sci/ desert/index.htm. See also “NATO Security through Science Security Issues of Desertification in the Mediterranean Region Debated at NATO Workshop—2–5 December 2003.” http://www.nato.int/science/news/2003/n031202a.htm

3 See, for example, *The Barcelona Process: The Euro-Mediterranean Partnership, 2001 Review,* 2nd edition (Brussels: European Commission, 2002), 13, available through the Europa server (http://europa.eu.int).

4 As one example of how this recognition might influence decision making, see *The Barcelona Process: The Euro-Mediterranean Partnership, 2001 Review,* 2nd edition (Brussels: European Commission, 2002), 13. http://europa.eu.int

5 In furthering this argument, this chapter intentionally blurs the distinction between environmental and human security, in favor of an extended security approach. For the best overall writing and conceptualization of “extended security,” reference the work of Emma Rothschild, Director of the Centre for History and Economics, Kings College, Cambridge University. As difficult as such “new” conceptions of security are, it seems worth noting that the United Nations Commission on Human Security continued to grapple with the definition of “security.”

6 Quoted in Thomas Scheetz, “The Limits to ‘Environmental Security’ as a Role for the Armed Forces”; paper provided by the author. Wæver’s original remarks, titled “Security Agendas Old and New, and How to Survive Them,” were prepared for the workshop on “The Traditional and New Security Agenda: Influence for the Third World,” Universidad Torcuato Di Tella, Buenos Aires, Argentina, 11–12 September 2000.

7 Norman Myers, “The Environmental Dimension to Security Issues,” *The Environmentalist,* 1986, 251.

8 Much of this chapter’s ideas and influence originated with an advanced research project at the U.S. Naval War College during the academic year 2000–2001. My thanks and acknowledgments, therefore, are due to Steven R. Hearne, an environmental specialist with the U.S. European Command, whose work stimulated this inquiry. Hearne’s project was later published as *Environment Indicators: Regional Stability and Theater Engagement Planning,* AEPI-IFP- 1001A (Atlanta, Georgia: U.S. Army Environmental Policy Institute, October 2001).

9 I should note that the European Command’s AOR (Area of Responsibility) is actually quite broad, encompassing geographic focus on fifty-five countries in the Euro-Mediterranean and Sub-Saharan Africa. Further, although functional responsibility

for the former Soviet republics of Central Asia has now shifted to the U.S. Central Command, all former Soviet republics in Central Asia are members of the Partnership for Peace (PfP) program and the Organization for Security and Co-operation in Europe (OSCE).

10 Hearne, 3–4.

11 For the purposes of the broad conceptual approach used in this chapter, the terms "framework" and "model" are used interchangeably. Some might clearly find this tact discomforting. As Hearne notes in his research, "The terms framework and model are often used interchangeably in different publications, [sic] however, framework implies a conceptual or basic arrangement or structure, whereas, a model is representative of some existing system. Robert Keen and James Spain define a model as "any representation of a real system [involving] words, diagrams, mathematical notation, or physical structures in representing the system…[the term] may have the same meaning as concept, hypothesis, or analog…[and] it must always involve varying degrees of simplification or abstraction." They use the examples of the food chain and the ecosystem to illustrate a "conceptual model." See Robert E. Keen and James D. Spain, *Computer Simulation in Biology: A Basic Introduction* (John Wiley and Sons, New York, 1992), 2–3.

12 The DPSIR model was derived in some measure from, and is more compatible (than the PSR framework) with, the United Nations [Commission on Sustainable Development] CSD Driving Forces-State-Response (DSR) model. Jesinghaus, *A European System of Environmental Pressure Indices,* 2.

13 Lisa Segnestam, *Environmental Performance Indicators: A Second Edition Note*, Paper No. 71, Washington, D.C.: World Bank, October 1999), 5–8.

14 United Nations Division for Sustainable Development, *Report on the Aggregation of Indicators of Sustainable Development*, Background Paper No. 2, for the Ninth Session of Commission on Sustainable Development, 16–27 April 2001, New York, 5–21. http:// www.un.org/esa/sustdev/csd9/csd9_docs.htm (5 April 2001).

15 The Sustainability Dashboard was developed in coordination with the International Institute for Sustainability's Consultative Group on Sustainable Development Indices. Peter Hardi and Alan AtKisson, "The Dashboard of Sustainability," Draft Design Specifications Document for the Consultative Group on Sustainable Development Indicators, October 1999, 3–4. http://www.iisd.org/cgsdi/dashboard.htm (3 April 2001).

16 United Nations Division for Sustainable Development, *Report on the Aggregation of Indicators of Sustainable Development*, 117–18.

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DESERTIFICATION AND ENVIRONMENTAL SECURITY. THE CASE OF CONFLICTS BETWEEN FARMERS AND HERDERS IN THE ARID ENVIRONMENTS OF THE SAHEL

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ABSTRACT

Traditional production systems in the Sahel are based on the integration of activities sharing and competing for renewable resources (water and soil fertility) under threat of desertification. A framework of relationships ranking from conflict to collaboration between human groups devoted to agriculture and pastoralism has been developed throughout history and has proven to be successful in sustaining the livelihood of the region's population. Changes in the economic, social and political structure of the Sahel related to the process of colonization and de-colonization substantially altered the way in which resource scarcity was dealt previously. In a context of widespread social tension and political instability, this is thought to have increased the likelihood of farmers-herders conflicts. In this paper, we explore the worsening security conditions of the rural Sahel in the light of the new environmental security theories, which help to widen the focus of conflict analysis bringing in social, political, economical and environmental issues that were formerly disregarded.

Keywords: desertification, environmental security, conflict and collaboration, farmers and herders, scarcity, Sahel.

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VIOLENT CONFLICTS AS MULTI-DIMENSIONAL PROCESSES WITH ENVIRONMENTAL IMPLICATIONS

The concept of security is evolving and enlarging in order to include a range of factors that make it fit better with its complex and dynamic nature. Because of this, it is moving from the narrowly militaristic understandings of threat, vulnerability and response towards a multi-dimensional, holistic approach (Dabelko *et al*., 1999). Among the wide range of layers that the new conception of security displays, the environmental, but especially the social and economic issues, have arisen as most significant (see Table 1 for a list of factors contributing to violent conflict). These ideas are embodied, for instance, in prevention tools like the *index of human insecurity* (IHI), which estimates the likelihood of violent conflict through considering four different environmental parameters (net energy imports, soil degradation, safe water and arable land) along with other economic, social and institutional factors (Lonergan *et al*., 2000), not unlike the UN *index of human development* (see epigraph 2.3).

Scarcity is a key concept when linking natural resource and security issues. Rees (1991) proposes 4 different types of scarcity related to fight for resources: i) *physical scarcity*, related to resources only available in a finite amount (broad definition), ii) *geopolitical scarcity*, meaning that (mainly non-renewable) resources are often distributed unequally on the surface of the Earth in such a way that some countries depend on deliveries from others, iii) *socio-economic scarcity*, concerning the unequal distribution between or within societies of purchasing power and of property rights to natural resources, and iv) *environmental scarcity*, in the sense that resources that have traditionally been regarded as plentiful are becoming scarce now because of the failure of human beings to adopt sustainable methods of management (mainly renewable resources such as water or fertile soil, as it is the case of land desertification). Scholars now agree that environmentally-induced conflict from renewable resource scarcity (thus, *environmental scarcity)* will become increasingly frequent because, unlike non-renewable resources, technological innovation and the market have only achieved limited success in developing substitutes for renewable resources (Dabelko *et al*., 1999). This might be consistent with some economic empirical evidence: the evolution of prices of non-renewable resources between 1870 and 1989 (Nordhaus, 1992) and the changes in the expected life of selected resources between 1970 and 1994 (Pearce, 2000) shows that most non-renewable natural resources, including fossil fuels such as oil, coal and gas, are becoming economically less scarce thanks to developments in the extraction techniques.

There are several ways humans may increase environmental scarcity over renewable resources (Homer-Dixon, 1991): i) decreased quality and quantity of renewable resources through exploitation/degradation at rates higher than the natural renovation of stocks (*supply-induced* scarcity); ii) increased population growth or per capita consumption (*demand-induced* scarcity); and iii) unequal resource access (*structural* scarcity). These sources can act singly or in combination when generating environmental scarcity and their interaction produces two particularly common phenomena that Homer-Dixon (1994) has named *resource capture* and *ecological marginalization*. Both are key concepts and will be properly presented when analyzing the farmers-herders conflict and its relationship with desertification (see epigraph 4.2).

This paper aims to analyze the farmers-herders conflict in a region vulnerable to desertification (the Sahel) under the framework of the renewable resources´ (water and fertile soil) environmental scarcity concept. However, in order to gain a broader picture of the subject the scope of the analysis has been enlarged and includes social, economical and historical dimensions along with environmental factors (focusing on desertification). Table 1 shows how environmental factors are less relevant compared to social, political and economic when trying to understand why conflict initiates because, as Libiszewski (1992, p. 8) points, “the environmental variables do not directly cause the conflict per se but instead make more salient the variables that can precipitate conflict”. Accordingly, it intends to understand to what extent the desertification process influences the farmers-herders conflict in comparison with the rest of contributing factors, following the holistic approach of conflict analysis.

Table 1. Factors contributing to violent conflict under the *holistic* paradigm

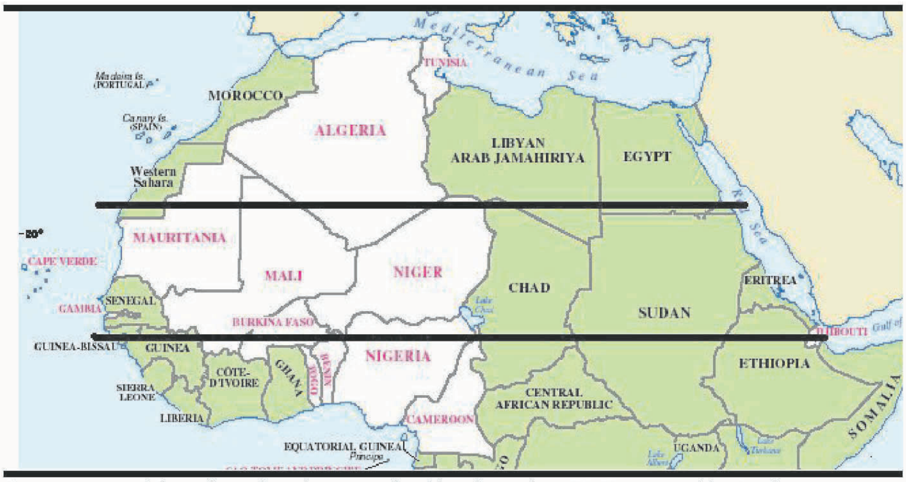
Contributing factor	Link to intrastate violent conflict	Link to interstate violent conflict	Strength of relationship
Political system	Probability of violence varies inversely with the degree of democratization.	Stable democracies are unlikely to experience violent conflict with one another.	*Strong*
Geographical contiguity		Neighboring states are more likely to experience conflict than non-neighboring states.	*Weak*
Ethnic fragmentation	Probability of violence increases with the degree of ethnic fragmentation	Ethnic linkages across borders increase the probability of conflict diffusion.	*Strong*
Population density	Probability of violence increases with population density.		*Strong*
Power status		If there is a substantial difference in power status, the probability of violence increases.	*Medium*
Previous conflict	Violent conflict in the previous two years increases the probability of violence.		*Strong*
Level of economic or human development	Prob. of violence varies inversely with the level of development.		*Strong*
Resource scarcity	Probability of violence increases with increased levels of resource scarcity.		*Weak*

Source: Dabelko *et al*., 1999.

FACTORS SHOWING INFLUENCE ON THE CONFLICT BETWEEN FARMERS AND HERDERS

Ecology of the Sahel and the farmers-herders relationship

The term *Sahel*, in spite of its variety of meanings in different fields, is widely acknowledged as the relatively narrow band South of the Sahara desert between the 150 and 600 mm isohyets covered by semi-desert grassland, thorn shrub and wooded grassland dominated by *Acacia* spp. (Wezel and Rath, 2002; Wickens, 1997). It can be considered as an *ecotone* because it puts into contact the desert ecosystem of the Sahara and the Northern edge of the African dry tropical environments, thus sharing features of both. Although biogeographically it connects the Atlantic coast of Senegal and The Gambia with the Red Sea in Eritrea, for the purposes of this paper we will refer of the Sahel as the Western half of that band (see Figure 1 for a sketch of the position and extension of the Sahel and Tables 3, 4 and 5 for a list of the countries hereby considered as the Sahel).



Source: own elaboration after the map of Africa from the UN Cartographic Section.

*Figure 1.*The Sahel in North Africa

Biophysical variables in the Sahel, mainly rainfall, are extremely irregular, which has led some authors to suggest that there are not "normal" rainfall levels (US Congress of Technology Assessment, 1986). This challenges the equilibrium ecological theory, unable to capture uncertainty and variability of arid environments, and makes concepts such as *carrying capacity* and *stocking rate* ineffective in predicting ecosystem productivity at least at local scales (Niamir Fuller, 2000). The region's non-linearity climatic patterns, along with other factors like the abundance of biological vectors of a variety of human and livestock diseases, create a uniquely dynamic but dangerous environment (Goldsmith *et al.*, 2002) as the hundreds of thousands of deaths related to the droughts of the 1960s and 1970s prove (IPCC, 2001). Because of this, primary production in the Sahel is sometimes only possible thanks to mobile pastoralism, an opportunistic form of land use that has proven to be highly adapted to the changing conditions of this environment. Agriculture barely exists below the about 400 mm isohyet (Blench and Marriage, 1999). This means that, at least in a substantial fraction of the Sahel, agricultural and pastoral production areas overlap. Consequently, they compete for scarce resources under threat of desertification (water and soil fertility), which is the base for the farmers-herders conflict presented here. But they also show a complex and well-developed collaborative behaviour based on the exchange milk, blood, leather, meat and manure for stove for agricultural products (local cereals like millets and sorghums), labour or grazing rights (Blench and Marriage, 1999; Blench, 2001b). In fact, we might consider that conflict and collaboration are the two sides of a wider framework of relationships between pastoral and agricultural groups, which historically developed as a way of coping with environmental variability.

Historical factors

Ethnic and religious diversity

History conditions, though not determines, the relationship between pastoral and agricultural people. Historical factors are relevant since the Sahel has been populated since the early stages of human evolution, as it is proven, for instance, by the fact that the world's oldest know stone tools, dating between 2.6 and 1.5 million years ago, have been found in Gona, Ethiopia (Semaw, 2000), on the Eastern side of the Sudano-Sahelian band.

Such an old history of human population in Africa, along with other factors like the diversity of environments, generated a high degree of ethnic, linguistic and religious *fractionalization*. Measures of ethnic diversity based on the ELF (*ethno-linguistic fractionalization*) index ranking from 0 to 100 show that Africa (especially the Sub-Saharan countries) is the most culturally diverse region of the world, accounting for a comparatively higher ELF than regions like Europe and the Americas (see Table 2).

Table 2. Ethno-linguistic diversity of Africa and other regions of the world (1960)

Country	**Europe & North America**	**Asia (South & East)**	**Latin American &Caribbean**	**Middle East & North Africa**	**Sub-Saharan Africa**
ELF value	15.5	47	17.5	18	72

Notes: ethno-linguistic diversity measured through the ethno-linguistic fractionalization index (ELF) ranging from 0 (minimum value) to 100 (maximum value) based on data from 1960.
Source: Elbadawi and Sambanis, 2000.

Table 3. Ethno-linguistic diversity of the main countries in the Sahel

Country	ELF value
Senegal	72
Gambia	73
Mauritania	33
Mali	78
Niger	73
Nigeria	87
Burkina-Faso	68
Chad	83
Average	**71**

Notes: ethno-linguistic diversity measured through the ethno-linguistic fractionalization index (ELF) ranging from 0 (minimum value) to 100 (maximum value) based on data from 1960. Source: Posner (2003).

These are all relevant facts because, according to Table 1, a strong correlation is supposed to exist between the factor "ethnic fragmentation" and the probability of violent conflict. Having in mind the subject of this paper, another fact to take into account is that many of the neighboring ethnic groups in the Sahelian region have been engaged traditionally in different land-use strategies, namely agriculture and pastoralism. This would be the case of many ethnic groups in the Sahel, as it happens in Senegal between the Woolof cultivators and pastoral Peule or Fulbe people (Warren and Khogali, 1992). Furthermore, the Sahelian band puts into contact the Muslim, Northern African people with the Sub-Saharan people whose original indigenous beliefs such as animism coexist with different Christian churches imported from Europe. As can be extracted from Table 4, the population of most of the Sahelian countries is divided between these two religious groups and it is believed that pastoral people in the Sahel are mainly Muslim (Blench, 1996). The idea behind these estimates is that different ethnic groups practicing different religions and devoted to different land uses can be more easily engaged in conflicts related to scarce resources competition.

Table 4. Religious diversity of the main countries in the Sahelian band

Country	Cults
Senegal	Muslim 94%; indigenous beliefs 1%; other 5% (mostly Roman Catholic)
Gambia	Muslim 90%; Christian 9%; indigenous beliefs 1%
Mauritania	Muslim 100%
Mali	Muslim 90%; indigenous beliefs 9%; Christians 1%
Niger	Muslim 80%; remainder indigenous beliefs and Christians
Nigeria	Muslim 50%; Christians 40%; indigenous beliefs 10%
Burkina-Faso	Muslim 50%; indigenous beliefs 40%; Christian (mostly Roman Catholic) 10%
Chad	Muslim 51%; Christian 35%; animist 7%; other 7%

Source: CIA World Data Factbook 2002.

However, it is still under discussion the influence of ethnic diversity on the likelihood of occurrence of conflicts. There is evidence based on statistical multi-variable analysis showing that, for a data set on civil wars throughout the world between 1816 and 1992, highly fractionalized societies have no greater risk of experiencing a civil war than more homogenous ones (Collier and Hoffler, 1998), although it seems that ethnic diversity becomes problematic when it borders *polarization* and one of the ethnic groups accounts for 60-40% of the population and can dominate the others (Collier and Hoffler, 2001). Similar quantitative analysis for the whole Africa suggest that ethnic diversity might have a deterrent effect on violent conflict (Elbadawi and Sambani, 2000). Whether this is also valid for more detail scales, particularly in the Sahelian region, is still to be proven, but it might be that the influence of ethnic diversity in violent conflict depended strongly on the local conditions. This would demand a rather case-by-case approach. Thus, in any case, attention must be paid to the ethnical and religious factors contributing to violent confrontation over natural resources.

Farmers and herders. An ancient conflict

It is likely that the origin of competition for scarce resources, namely water and soil fertility, between agricultural and pastoral activities goes back as far as the Neolithic. The myth of Cain and Abel (*Genesis* 4), recorded in the Bible but probably existing much earlier in the form of an oral tradition, can be interpreted as a sublimation of the recurrent confrontation that might be happening in areas where farming and herding overlapped in Middle East in ancient times. Analogously, some traces of the conflict are thought to be found in the traditional Indian epic poem Maharabata, which is understood nowadays by modern ecologists as a recorded proof of the war between the sedentary farmers of the Hindus valley and the incoming, riding nomads from the steppes of Central Asia who finally subdued them by 1500 BC (Gadgil and Thapar, 1990).

Within the old tradition of competition for resources, pastoral people have taken in many cases the role of aggressors, whereas agricultural people have been subject to recurrent raiding and stealing of their crops by the former. This has to do with the way farmers and pastoralists organize themselves and the territory they occupy. Nomadic pastoralists usually locate on marginal, desert environments and their way of life is based on moving across long distances and reaching the peaks of primary production they have identified in the many years of adaptation to this environment. Thus, their agricultural activities were minimal and relied on settled farmers for the agricultural supplies, as the idea of *complementarity* between agriculture and cattle-raising shows (Blench, 1996). As Harris (1990) and Harris (1996) suggest, pastoralists then felt very often tempted to improve their negotiating position attacking the villages of farmers, and did so thanks to the stronger military capacity and mobility that riding horses or camels gave them. If successes in raids became recurrent, the farmer population would have then considered them as their lords and the pastoralists would have improved their position becoming taking the political and military leadership. Nevertheless, the most common output of this process is thought to be the sedentarization of the nomadic conquerors, who would have then adopted the agricultural way of living in order to feed all the population under their rule (*ibid*). In the Sahel, such a behaviour has been recorded, at least, for the Tuareg herders in Northern Burkina Faso (Banzhaf *et al*., 2000).

Examples drawn from the history of Eurasia, Africa and America support this idea (Blench, 2001a). Probably the best known expanding pastoral people have been the Arabs and the Mongols who, in spite of their low number, rapidly spread across vast distances, and settled, ruled over and mixed with the local population of invaded areas (Harris, 1990). In West Africa, the nomadic Fulbe launched a *jihad* in the early 19th century which transformed the political map of the Sahelian region (Blench, 2001b). The idea behind these evidences is that complex systems, such as environmental and cultural, show *inertias* in their long-term behaviour, thus making historical factors to be considered when analyzing the farmers-herders relationship.

Underdevelopment and social changes

Between the multiplicity of causes behind the sort of conflict presented here, the social, economic and political factors probably arise as the most influencing (see Table 1). This is relevant since Africa is known for its economic weakness and political instability: most of the African countries and the whole of the Sahelian states belong to the so-called *third world*. This has to do, on the one hand, with the way African people organize themselves (that can be exemplified with the deeply rooted *clan* loyalty) and, on the other hand, with the colonization and decolonization of the continent (de Temmerman, 2000). To a certain extent colonization forced Africa to become a source of natural resources and labour force (in the form of slavery) for the colonizing powers, which deeply influenced the traditional political organisation of the colonized countries and started a period of profound changes whose consequences are still felt nowadays.

These changes haven been very intense in the Sahel in the second half of the last century and have reshaped the demographic features of the region. After World War II, Sahelian population, who used to have very low growth rates (also because of the depopulating effect of slavery) and used to be predominantly rural, started to grow very fast, especially in the cities, where population growth rates have been substantially higher than the average (Pieri, 1992; UNDP, 2003 – see Table 5 for figures on total and urban population growth rates). The urbanisation of the Sahelian population has to do partially with the rural-urban migration happened as a response of rural societies to the droughts and famine in the 1970s (Brockerhoff, 1994). In fact, it is thought that migration is an important demographic response to poverty and environmental stress in Africa (Krofkors, 1995), and the Sahel would not be an exception, rather a good example, for this. Rural urban-migration in this context points out the difficult conditions that Sahelian people are facing to ensure their livelihood. They might be suffering from the loss of what Sen (1981) called the *entitlement of food* (resources that can be used to produce food or to obtain through exchange), showing the large extent of poverty and deprivation in which the region is immersed.

Sub-Saharan Africa is one of the poorest regions of the world. The average living standards of its people are presently as low as they used to be 30 years ago and their income is substantially lower than other typically underdeveloped regions such as Latin America or China (Kim, 2003). These world regions are immersed in what has been called a *growth tragedy* (Cohen, 1998) that prevents them to achieve the GDP growth rates needed for economic and social development. In fact, the average value of 46 Sub-Saharan countries´ growth rates for the 1990s reached 0.105%, which means that most of these countries witnessed negative growth until recent years (Kim, 2002). Similarly to what was presented in epigraph 2.2.1, it has also been argued that ethno-linguistic fractionalization might be a major factor hindering the development of the region (Easterly and Levin, 1997). However, multiple-variable analyses have rejected this hypothesis (Kim and Kim, 2003), suggesting that it is not ethnic diversity but lack of democracy in a context of diversity what leads to the growth tragedy (Collier, 1999).

Table 5. Development indicators of the main Sahelian countries

Country	**Total population 1975-2001**(1)	**Urban population 1975-2001**(2)	**GDP per capita** (3)	**Life expectancy at birth**(4)	**Adult literacy rate**(5)	**HDI rank**(6)
Senegal	4.8 – 9.6	34.2 – 48.1	1,500	52.3	38.3	156
Gambia	0.6 – 1.4	17.0 – 31.2	2,050	53.7	37.8	151
Mauritania	1.4 – 2.7	20.3 – 59.0	1,990	51.9	40.7	154
Mali	6.3 – 12.3	16.2 – 30.8	810	48.4	26.4	172
Niger	4.8 – 11.1	10.6 – 21.0	890	45.6	16.5	174
Nigeria	54.9 – 117.8	23.4 – 44.8	850	51.8	65.4	152
Burkina-Faso	6.1 – 12.3	6.3 – 16.9	1,120	45.8	24.8	173
Chad	4.1 – 8.1	15.6 – 24.2	1,070	44.6	44.2	165

Notes: (1) total population in million people; (2) urban population as % of total; (3) GDP per capita in PPP (*Purchase Power Parity*) US$; (4) life expectancy at birth in years; (5) adult literacy rate as % of population age 15 and above; (6) HDI rank as position in the list of 175 countries. Source: UNDP, 2003.

The picture drawn above applies for describing the situation in the West Africa Sahel, if it is not too optimistic. Most of the countries in this region rank very low in the UN Human Development Index list and three of them (Mali, Niger and Burkina-Faso) are among the five least developed countries in the world according to this criterion (UNDP, 2003 – see Table 5).

A number of internal and external factors have been suggested to explain this development trap (Kim and Kim, 2003): low population density, a difficult environment (tropical climate, low soil quality, etc), low size of countries (a legacy of the colonial era), high volatility of prices in their export products, failure to coordinate policies, lack of state governance and democracy in decision-making systems, inefficient and corrupt bureaucracies, etc. Some of these explanations point that the way politics are performed in Africa is one of the constraints the development of the

Sahel. In fact, political regimes in the Sahelian countries, as in many other African countries, rank between *presidential authoritarian regimes* and *military dictatorships* (Nyong´o, 2002).

Besides, the progressive globalisation of the Sahelian economy started by colonialism in the 19th century has forced the local consumption and, above all, production patterns to adjust to the fluctuations of international markets. For instance, peanuts were promoted by colonial powers as an export crop in Senegal and The Gambia since the 1830s, which made local farmers shift from subsistence agriculture and expand their agricultural land to marginal areas and provoked sometimes the disruption of the migratory patterns of pastoralists (US Congress of Technology Assessment, 1986). Then, after the 1960s the price of this export crop dropped and since then remained low, making the rural income of Senegal more than halve in the period 1960-1977. This forced Senegal to become a net importer of food and did not help the falling of purchase power of the rural population (Sokona *et al*., 2003). Globalisation also affected traditional common-resource management regimes, which had negative consequences on the long-term availability of scarce resource such as fertile land and water. In Northern Burkina Faso, the decision of weakening the formerly ruling Tuareg people was done by corralling groups into separate designated areas and restricting the movement of herds. Although attempted to be reversed afterwards, it finally led, along with other factors such as population growth, to the abandonment of the traditional, communal management of resources based on complementarity between agricultural and livestock production, which has been substituted by much more anarchic and selfish attitudes towards shared natural capital (Banzhaf *et al*., 2000).

Sahelian countries are immersed in a development trap characterized by low income levels and literacy rate, growing population density, rural-urban migration, lack of democracy and political rights, slow or negative economic growth, inequality and social tensions. These are all factors significantly increasing the probability of conflict (Dabelko *et al*., 1999; Collier and Hoeffler, 2001) and it is not by chance that the all of them rank low in the *human security index*[45] (see epigraph 1) (Lonergan *et al*., 2000). Although fight for resources between farmers and herders is quite a

[45] All Sahelian countries show values of IHI (*Index of Human Insecurity*) above 5 and some of them (Nigeria, Chad, Senegal and Guinea Bissau), above 6. In contrast, OECD countries are featured by IHI values in the range 1-4. The index is scaled from 0 to 10 (Lonergan *et al.*, 2000).

specific type of conflict, it is clear that it will happen more easily in a context of widespread social and political instability, as it is the case.

CASE STUDIES

Niger

Desertification and environmental change are thought to be connected with violent conflict between agricultural and pastoral people in Nigeria. Fulani herders have clashed in recent years with neighboring agricultural ethnic groups, such as the Zarma (also known as Djerma), in Niger. Furber (1997) reports that, in May 1997, in the village of Falmaye some 90 kilometers Southeast from Niamey, seven people were killed and 43 wounded when Zarma villagers attacked a Fulani camp as a reaction to the death of a Zarma in a fight with Fulani herders earlier in the day. These two ethnic groups also clashed in the region of Téra, 160 kilometers Northwest from the capital. Though no deaths were reported, 35 people were wounded.

The Fulani are a true pan-African ethnic group, primarily Muslim, whose herds extend from Senegambia to the Red Sea along the whole Sudano-Sahelian band to which they have adapted their resource use patterns. This includes transhumance, which moves them northwards in the rainy season and brings them South in the dry season. Given that they are scattered over a long distance, they frequently mix with other ethnic groups practicing agriculture, with whom they exchange goods and services. For instance, their camps are welcome in the Southern, agricultural region of the Sahel, since cattle dung is the best manure in the area (Matsushita, 1999). In Niger southwards the Sahara desert, where the conditions allow agriculture on the most fertile areas, they often share their land with other agricultural people such as the Zarma. These live primarily in Western Niger, but also in Burkina Faso and Nigeria, where they grow millet, sorghum, rice, corn and tobacco, and cash crops such as cotton and peanuts. They also own livestock because they like complementing their diet with dairy products (Warren *et al*., 2001). In the Southwestern region of Niger, where the Zarma arrived by the 19th century, the Fulani are minority, though the original inhabitants (Batterbury, 2003). There are evidences of rapid soil erosion, whose short-term effects are felt by both Zarma and Fulani (Warren *et al*., 2002), and of environmental change (biodiversity loss and reduction of wooden areas) following land intensification and migration (Batterbury, 2001). This might be indicating that social and historical conditions (a minority of pastoral people feeling threatened by incoming farmers, who become the dominant ethnic group) added to environmental factors including desertification processes (intensification of primary production, soil erosion, loss of plant cover, etc) might lead to violent conflict between farming and herding communities.

Nigeria

Blench, (2001a, p.15) tells how the colonial government favoured the Muslim Hasa-Fulani herders in Nigeria, who got to control the local juridical system. During this period, court cases between farmers and herders tended very often to be decided in favour of the latter. Independence came and farmers began gradually to take control of local authorities, and their appointees started making decisions in courts. The result was a reversal of the previous bias, meaning that farmers were compensated for their historical mistreatment by local justice. In such a way, part of the historical basis of the conflict was set. Afterwards, religious, socio-economic and environmental factors helped to increased tension between competing communities, which led to an open conflict in recent years as it is shown below.

The confrontation between Muslim Hasa-Fulani herders and mainly Christian neighbouring agricultural communities has already reached the level of armed confrontation and produced numerous casualties in the past few years. The UN Integrated Regional Information Networks, the UK Home Office and the British Broadcasting Corporation (BBC)[46] have reported on continuous, widespread violence in the Northern and central states of Nigeria throughout 2002 and 2003:

- January 8, 2002: dozens of people died and hundreds were displaced in clashes between local farming communities and nomadic Fulani herders in Mambilla plateau, Northeastern Nigeria. The fight broke out in Tonga Maina village following a dispute over grazing land.
- February 22, 2002: at least 23,000 Fulani herders fled Nigeria’s Eastern Taraba State to Cameroon to escape clashes which broke out between several communities in Mambilla Plateau.

[46] Metasource: European Country of Origin Information Network (URL: http://www.ecoi.net/doc/en/NG/content/7/1051-1109)

- May 30, 2002: at least 10 people died in clashes between nomadic Fulani herdsmen and local people in parts of central Nigeria's Plateau State. These fights were part of an emerging pattern since a major upheaval in 2001 in the state capital, Jos, in which more than 500 people died.
- June 20, 2002: at least 30 people were killed in clashes between farmers and herders in Barkin Ladi local council area of Nigeria's central region Plateau State. The clashes were sparked by a dispute over grazing land in the village of Kassa.
- July 15, 2002: at least 12 people were killed in an outbreak of ethnic and religious violence between Fulani herders and agricultural people in the Plateau State, central Nigeria. Farmers blame some of the attacks on Fulani herdsmen who, would have been seeking to avenge the death of one of their chiefs in the September 2001 Jos conflict. The herdsmen in turn accused the indigenes of giving them ultimatums to leave land which, for decades, had been their traditional grazing areas.
- March 4, 2003: more than 100 people were killed in clashes between ethnic groups living side-by-side and competing for limited resources in the Northeastern state of Adamawa.

Reporters from the information agencies found connections between these conflicts and the environmental changes happened in the arid lands of Nigeria, though no formal explanation was offered by institutions. However, some facts worth to take into consideration might illustrate the proposed influence of desertification on violence.

The 38% of Nigeria's surface, accounting for 32% of the Nigerian population, is under desertification threat or in desert-like condition (Odumosu, 2002). There is general consensus that desertification is the primary environmental concern in the drylands, the most affected area. In the Northern states closer to the Sahara desert, between the 50% and 75% of the territory is being affected by desertification forcing people and their cattle to migrate southwards. Incoming population and livestock are absorbed mainly by buffer states in the center of the country, also under threat of desertification in the 10%-15% of their land (Federal Ministry of the Environment of Nigeria, 2001). One of them is the Plateau state where the conflicts aforementioned were reported in 2002. The consequences of this process of environmental degradation are challenging the livelihood of many pastoral nomads because almost 90% of the cattle in the country is located mainly in the Northern states. Besides, herds from neighbouring countries, especially from Chad, Niger and Cameroon, are attracted to these zones because of the abundant supply of fodder around the patches of the Lake Chad wetland and beyond (*ibid.*). Worsening environmental conditions are most probably caused by socio-economic pressures, basically population growth (between 1975 and 2001, the country's population doubled, rising from 54.9 million to 117.8 million people) and low level of human development (Nigeria ranks 152 in the Human Development Index list) (UNDP, 2003). Given these circumstances, it is possible to understand why desertification is playing a certain role in sparking off conflicts for increasingly scarcer land and water resources between settled farmers and incoming herders.

CONCLUSIONS

Featuring conflict between farmers and herders in the Sahel

Conflicts between farmers and herders are a specific facet of the spectrum of social, economic and political tensions that are taking place in the Sahel in the recent past. Although it is difficult to establish comparisons between different violent events, some common properties that may help to understand this typology of conflicts have been identified:

- Conflict between farmers and herders is to be understood in terms of competition for scarce renewable resources under threat of desertification, namely *water* and *soil fertility*. In the past, resource availability in the Sahel was determined by annual rainfall and confrontation was part of a wider framework of relationships developed throughout history based on cooperation and exchange of goods and services in periods of abundance and on violent competition in periods of scarcity. Recently, this traditional way of dealing with environmental variability has been deeply modified and resource availability, although still dependant on biophysical variables, has to do also with a number of demographical, social and economical reasons (see epigraph 2.3). Besides, it is also clear that it is linked to the notions of *conflict* and *crisis* that is usually connected to mobile pastoralism (McGinnis, 1999; Blench, 1996).
- Although not in all cases, it is very likely that conflict usually happens as a violent reaction of pastoralists whose traditional grazing areas or transhumance pathways are invaded by incoming farmers. Transhumant pastoralism in the Sahel, as in many other parts of the world, is a

declining activity (Blench, 2001a; 2001b). At the same time, population growth and economic changes have favored other forms of less mobile of livestock production, as well as agriculture (Wezel and Rath, 2002; Blench and Marriage, 1999). This change in the production strategy of the Sahel has occurred along with unexpected variations in rainfall during the second half of 20th century. As Puigdefábregas (1995, p. 65) suggests as follows, the recent *ecological history* of the Sahel also helps to explain encroachment onto the grazing land of pastoralists: "between 1940 and 1960, rainfall in the sub-Saharan band was clearly over the average. As a reaction of this, many farmers and herders headed North and established in drier lands where, formerly, only nomadic pastoralism existed. In the middle 1970s, drought trapped these people in a *cul-de-sac* because further North only desert could be found and the South, from where they were coming, had been already occupied by increasing agricultural populations ". In this way, the overall region resource-use intensity increased and, thus did the likelihood of conflicts between long ago settled pastoral people and incoming farming and herding migrants (Wezel and Rath, 2002).

- They are taking place in a region prone to violent confrontation (Lonergan *et al*., 2000; ICG, 2004) between political, economic or even *ecological* rival factions. Sahel is undoubtedly one of the poorest and most underdeveloped regions in the world, where political and social instability is widespread and weak states are unable to control and/or supply with basic services large fractions of their territory (see epigraph 2.3). There, former social order previous to colonization has to a given extent disappeared but not substituted after the withdrawal of colonizing nations, as Banzhaf *et al*. (2000) recorded in Burkina Faso. This has made the region vulnerable to violent conflict and provides a proper context to find non-peaceful means of dealing with resource scarcity between pastoral and agricultural groups.
- Conflicts for resources between farmers and herders have implications in terms of ethnic and religious diversity. The Sahel is an *ecotone* (see epigraph 2.1) but also a borderline between two different cultural universes: the Muslim, Arab-related Northern Africa and the black, Sub-Saharan Africa where traditional beliefs such as animism cohabitate with various interpretations of the Christian faith (see epigraph 2.2.1). Although evidence points that ethno-linguistic diversity is not enhancing the probability of conflicts in Africa as a whole, this issue might be important when analyzing this kind of conflicts in the Sahel. There, differences between farming and herding communities are

not only in terms of resource-use systems (Warren and Khogali, 1992), but also from an ethnic and religious standpoint (Blench, 1996), which might be influencing negatively the existing tensions between them.

- These are mainly intra-state, low-intensity, long-lasting and recurrent conflicts, as many other environmentally-induced conflicts, which are "sub-national, diffuse and persistent in character" (Homer-Dixon, 1994, p. 1) As it can be extracted from both cases studies (see epigraphs 3.1 and 3.2), conflicts between farmers and herders, although serious and involving hundreds of deaths, are not as violent as those happening in many other countries in Africa (ICG, 2004).
- The intensity of the violence reached in the clash is dependant on the level of technical development of warfare available for confronting parties. This is especially relevant because there is mounting evidence showing that small arms are becoming increasingly more available in the Sahel (van der Graff, 1999) and the whole Africa (Lumpe, 1999).

Linking desertification and environmental security in the Sahel

The notion of desertification seems to be directly connected with the Sahel since this term was coined after the severe droughts that razed the region in the late 1960s and early 1970s (Puigdefábregas, 1995). Following the concept of *environmental security*, it is widely recognized that this process of resource degradation must be taken into account for understanding and preventing conflicts in arid environments. The UN Convention to Combat Desertification (2003) points out this relationship explicitly: "desertification exacerbates poverty and political instability**.** It contributes significantly to water scarcity, famine, the internal displacement of people, migration, and social breakdown. This is a recipe for political instability, for tensions between neighboring countries, and even for armed conflict. Evidence is mounting that there is often a strong correlation between civil strife and conflict on the one hand and environmental factors such as desertification on the other". Other institutions such as IUCN and OECD (Dabelko *et al*., 1999), refer to this issue in similar terms. In the same direction, Eswaran *et al*. (2001) found that large fractions of the Sahel are *global desertification tension zones* comprised within the 11.9 million km^2 (containing as many as 1.4 billion inhabitants) of very high-risk class areas where major conflicts related to the reduced ability of the land to support people in agriculture-based communities are expected to happen.

The process leading to an increased probability of conflict between agricultural and pastoral people in the Sahel are consistent with the phenomena of *ecological marginalization* and *resource capture* proposed by Homer-Dixon (1991; 1994) presented in epigraph 1. On the one hand, resource capture happens when a decrease in the quantity or quality of renewable resources coinciding with population growth encourages "powerful groups within a society to shift resource distribution in their favour. This can produce dire environmental scarcity for poorer and weaker groups whose claims to resources are opposed by these powerful elites" (*ibid*., p. 10). Although it is not strictly possible to speak of *elites* in this case, there is evidence, as it was shown in epigraph 4.1, showing that farmers are occupying the traditional grazing lands and transhumant pathways of Sahelian nomadic pastoralists, forcing them to move to ecologically marginal areas (Puigdefábregas, 1995; Wezel and Rath, 2002). However, the situation in the rural areas of the Sahel is better described through the notion of *absolute scarcity* (meaning that resource scarcity is suffered by all members of society) than through *relative scarcity* (which also is to be found here, since not all members of the society are equally poor and enjoy the same access to resources). On the other hand, ecological marginalization occurs when population growth and unequal resource access combine to produce four social effects particularly relevant for violent conflict: i) decreased agricultural production; ii) decreased economic productivity; iii) population displacement; and iv) disrupted institutions and social relations (Homer-Dixon, 1991). All these effects are in some extent present in the recent past of the region. As epigraph 2.3 pointed, Sahelian and other Sub-Saharan countries have experienced negative economic growth along the 1990s (Kim, 2002), which might be related to declining soil fertility that has already been registered in Mali and Niger (World Resources Institute, 1998). This has been cause, among other factors, of extensive rural-urban migration and has drastically increased the share of urban population of Sahelian countries (UNDP, 2003 – see Table 5). Besides, the Sahel (and other African regions) suffered from authoritarian regimes and widespread political instability (Nyong´o, 2002) after the disruption occasioned by the process of colonization and de-colonization. Again, the multiplicity of causes and factors linked to violent conflict is visible.

However, it must not be forgotten that environmental degradation is only a factor, probably not the most significant, related to violent conflict. The Sahel is a region of widespread *food insecurity* whose inhabitants have to face extremely difficult conditions to ensure their livelihood. This is source of a complex net of social tensions and political instability which, although cannot be isolated from environmental conditions, are the main reason for understanding conflict. Similarly, the type of conflict discussed here is only one of the forms environmental degradation links to human insecurity in rural areas, but other effects are to be found. For instance, it is recognized that human insecurity in urban areas related to environmentally-induced rural-urban migration is expected to increase in underdeveloped countries (Gizewski y Homer-Dixon, 1995), as it is the case of the Sahel.

Things are still rapidly changing in the region. Population will be growing fast at least during the first part of the current century and consequently pressure on resources will increase as well (Pieri, 1992). Other important changes are expected to happen in the medium and long-term because of *global warming*, which will set the scenarios determining the evolution of the farmers-herders relationship in the Sahel. There is no agreement on whether climatic conditions, measured as water availability, will worsen or improve along the 21st century but it seems that by the 2100 the Sahel could be better irrigated than in the last forty years (IPCC, 2001, p. 495). The way in which people, mainly in rural areas, will adapt to climate change displaying coping behaviours and increasing preparedness based on the experience of the 1960s and 1970s droughts will probably determine the long-term effect of climate change in Sahelian societies (Dietz *et al*, 2004). Blench (1996, p. 3) argues for the recent past that it is "likely that resource conflict is more prevalent than earlier in the [20th] century and that this is not merely an illusion generated by more research. There are more people competing for fewer resources and there are more perceived resource arenas." This could be also the case for this beginning century. Many factors evolving simultaneously will decide whether the probability of conflicts between farmers and herders will enlarge or decrease in the future. However, it is very probably that the surest way to encourage Sahelian agricultural and pastoral communities to deal more peacefully with resource scarcity is improving the overall living conditions of the Sahelian rural population.

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THE RELEVANCE AND CONSEQUENCES OF MEDITERRANEAN DESERTIFICATION INCLUDING SECURITY ASPECTS

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ABSTRACT

Desertification is a relatively new term but it is also an old issue in the European Mediterranean zone corroborated by the abundance of historical references highlighting the concern of different cultures on important land degradation processes in the region. The perception of this issue has been changing through time with periods of more environmental sensitivity and awareness alternating with periods of less attention and sensibility. In recent decades, a conceptual evolution has occurred, passing from a vaguely defined but real problem to a progressive assimilation and clarification of the physical and socio-economical processes involved, their factors, causes and also the impacts and consequences. In February 1994, the United Nations Convention to Combat Desertification (UNCCD) came into being. The UNCCD dedicates one of its Annexes to the specific problems of affected countries of the Northern Mediterranean region.

The regional Annex for the Mediterranean identifies the particular conditions of the region responsible for the threat of desertification processes. Among others, it specifies the semiarid conditions of the countries of this region (Spain has 63.5% of its territory affected by semiarid climatic conditions, Greece has 62%, Portugal 61.5%, Italy has 40% and France 16%), the seasonal droughts, the very high rainfall variability and sudden and high-intensity rainfall. The main factors and causes of desertification processes acting in Europe operate in different temporal and spatial contexts influencing the course of the natural processes involved in desertification. At the global scale, both natural (mainly atmospheric factors) and socio-economic factors (economical, cultural and political) influence the desertification processes. At the European scale, the factors acting are essentially physiographic, meteorological, economic and cultural aspects, and operate over large areas (e.g. river basins, mountain massifs, coastal zones, etc.). At the local scale, the specific physiography, soil types and uses, cultural traditions and land management are relevant factors influencing the desertification processes. A review is presented on the efforts made to evaluate desertification at the global and European scales.

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The consequences of Desertification also include security issues. The concept of Buzan (1998) on Societal Security should be expanded to include direct and indirect consequences of desertification which affect security aspects such as water scarcity, agricultural-food production, increase in the impacts of flooding, extension of forest fires, annual and interannual drought effects. Also other security aspects affecting Northern Mediterranean countries should be considered such as border security and problems derived from integration and cultural identity of emigrants.

Keywords: Desertification, Mediterranean Region, Evaluation of desertification, Security.

INTRODUCTION

Desertification is considered as one of the most serious environmental problems at a global scale. It affects the drylands of the five continents and has strong relationships with climatic change and loss of biodiversity. According to the United Nations Framework Convention on Climate Change (UNFCCC), "countries located in arid and semiarid zones, or zones prone to flooding, drought and desertification are particularly vulnerable to the adverse effects of climate change". Changes in temperature, evaporation and rainfall can result in aggravation of desertification in the most critical regions. Furthermore, desertification also influences climatic change as it modifies the hydrologic cycle (humidity, rainfall, albedo, evapotranspiration, etc.) of the affected area. On the other hand, desertification leads to a decrease of biodiversity of ecosystems suffering degradation processes. In fact, the Mediterranean ecosystems threatened by desertification are characterised by possessing a great richness of species, which is drastically diminished when degradation processes act.

The global dimension and scope of desertification processes have the following figures:

Over one billion people affected. In the worst case, people affected by desertification lose the productivity of their land and natural resources and they become forced to migrate to other areas for surviving.

Desertification has a global dimension. It affects 70% of the total dryland surface in the world. In fact, drylands of all the continents are affected by degradation processes leading to desertification. This shows that desertification is an important environmental issue that should be undertaken at global scale.

More than 100 countries affected, mostly underdeveloped but also developed. This points out that desertification is not only a relevant issue on developing countries.

Desertification is also a crucial and increasing environmental issue today in Europe that requires important attention and efforts for its control and mitigation. The European continent has the largest areas of drylands susceptible to desertification in comparison with the other continents (UNEP, 1992). Desertification processes affect between 8-10 per cent of the total European land from low to high degrees of degradation. Specifically, the European Mediterranean Region is particularly sensitive to desertification processes due to fragile environmental conditions. The threatened countries are: Spain, Greece, Portugal, Italy, France, Croatia, Bosnia-Herzegovina, Serbia-Montenegro, Albania, Malta, Cyprus, Bulgaria, Ukraine, Armenia.

It is important when considering the implications of desertification in Europe to review the concept, perception, evaluation and scope of desertification as well as implications on security issues. This evaluation forms the basis of this paper.

WHAT IS DESERTIFICATION?

Desertification is not a new concept. The first references to this process appears in the Codex of the Teodosio II (438 A.D.) with several references to the *agri deserti* or abandoned zone because of its low productivity or as consequence of military campaigns.

At the scientific level, Aubreville (1949) used this term for the first time to refer to soil degradation processes in tropical humid zones. However, the concept was not recognized world-wide until the United Nations Convention on Desertification (UNCOD) held in Nairobi (Kenya) in 1977, organised by the United Nations Environment Programme (UNEP). This Conference and the publication of the World Map of Desertification Risk (FAO, UNEP, UNESCO and WMO, 1977) were the trigger and warning announcement on the extension and consequences, at world-wide scale, of desertification processes. Early European initiatives started soon after the UNCOD meeting. Six years after (1984), in Mytilene (Greece) the first European scientific meeting on desertification was held under the sponsorship of the EU (Fantechi and Margaris, 1984). A few years later (1987), in Valencia (Spain), the second European conference on desertification was held, sponsored by the CEE, Generalitat Valenciana and the CSIC: “Strategies to Combat Desertification in the Mediterranean Europe” (Rubio and Rickson, 1990). Previously, in 1982, under UNEP sponsorship, Spain lead off an ambitious research programme on desertification LUCDEME (Lucha Contra la Desertificación en el Mediterráneo) co-ordinated and founded by ICONA, and in which collaborated numerous Spanish Universities and CSIC centres.

Throughout the 1980s, no clear definition of desertification was broadly accepted. For the UN organizations (UNEP, UNCOD, 1977) desertification meant “the process of conversion to desert the zones that climatically are not desert”, or “the progressive decrease or destruction of the soil biologic potential that in its last instances could conduct to desert conditions**”**. These wide definitions, with no geographical or bioclimatological restrictions and without specifying involved processes or causes, were the most widely used because of their synthetic character and ease for transmitting a warning and developing awareness. As such, it was able to mobilise international organisations, the scientific community and the general public. Together with it, it has generated important resources to tackle the fight against this process in Third World drylands.

However, the lack of precision of these definitions gave place to certain confusion and also to the proliferation of many other definitions and different scopes over the meaning of desertification. Rubio (1995) made a study on the evolution of the concept.

In the nineties, UNEP redefined its initial version to consider it as “land degradation in arid, semi-arid and dry-subhumid areas as a basic result of adverse human conduct” (UNEP, 1991). In this definition, the term “land” includes the soil, the local hydrological resources, the land surface and the natural vegetation. “Degradation” implies the reduction of the resources potential by one or several combined processes acting on land. These processes are: water erosion and sedimentation, decrease at short term of the quantity and diversity of the natural vegetation or diminution on crop production, and soil salinization and sodification.

Afterwards, and as result of the adopted agreement in the Rio de Janeiro Conference (June, 1992) by the United Nations General Assembly, it was elaborated and finally approved in Paris, in October 1994, at the “International Convention to Combat Desertification in Countries Affected by Serious Drought or Desertification, mainly in Africa” (UNCCD). This Convention on Desertification, together with those on Biodiversity and Climate Change established the international setting of the United Nations to undertake the present main global environmental problems. UNCCD includes a new definition adopted by consensus among more than a hundred countries, which establishes a better conceptual framework. This definition (article 1) determines that:

- *desertification* means "the land degradation of arid, semiarid and dry-subhumid areas resulting from various factors including climatic variations and human activities".

Related to the 1994 definition, an important nuance is added, the "climatological variations", as one of the key factors in the triggering of desertification processes and relating by this way the issue of arid lands degradation to the climatic change problem.

- *land degradation* means "reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rained cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: i) soil erosion caused by wind and/or water; ii) deterioration of the physical, chemical and biological or economic properties of soil; and iii) long-term loss of natural vegetation".
- *arid, semi-arid and dry sub-humid* areas means "areas, other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.65".

THE UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION AND THE ANNEX FOR THE NORTHERN MEDITERRANEAN

The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992, established the paradigm and referred to the need for global approaches for undertaking some environmental issues. It also highlighted that a new responsibility for environmental protection had to be adopted by all countries in order to achieve a sustainable development at global level. One of the main outputs of the Conference was the action plan for the 21st century ("Agenda 21"). This Agenda, the Declaration of Principles on Forests, and the Conference itself contain strategies and integrated measures for combating land degradation and for promoting sustainable development in all countries (UNCED, 1992a).

Although the Desertification issue was implicitly taken into account by the Conference through the declaration of intentions, the formulation of guidelines on resource management, the establishment of measures for nature conservation and fight against environmental degradation, it did not reach the emphasis and attention given to the Convention on Biodiversity and on Climate Change. However, African countries affected by desertification, with the assistance of some developed countries having the same environmental threat, managed to get the commitment of the UN General Assembly to elaborate a Convention on Desertification (UNCCD). The Convention was eventually signed in Paris in October 1994, and came into force in February 1997, after having been ratified by more than 50 countries (and now over 190 countries).

The Convention contains 40 articles and four Regional Annexes that include some innovative appraisals in relation to previous international environmental law, such as a new general "bottom up" approach.

The Convention emphasises the need to "adopt an integrated approach addressing the physical, biological, and socio-economic aspects of the processes of desertification and drought".

The Convention also emphasises the attention to the economic aspects of environment, both internationally and within nations, and highlights the importance of trade and marketing arrangements to enable desertification to be tackled effectively.

The general obligations of the Convention (article 4) refer to the relevance of co-operation within inter-governmental organisations, within regions and sub-regions, and internationally. Parties must "*promote co-operation among affected country Parties in the fields of environmental protection and the conservation of land and water resources, as they relate to desertification and drought*".

An important aspect of the Convention refers to the relevant role given to the whole society (specially to non-governmental organisations) for combating desertification. The Convention also recognises the importance of the private sector for this purpose.

In relation to the scientific and technological efforts for combating desertification, the Convention includes a Committee on Science and Technology (CST) and emphasises the way that local populations can use scientific knowledge, and contribute to it. It has flexible and potentially effective review mechanisms, and provisions to ensure co-operation among countries and international organisations.

Concerning the Annex for the Northern Mediterranean region, the article 2 specifies the particular conditions of the region that make it susceptible to desertification, as follows:

(a) semi-arid climatic conditions affecting large areas, seasonal droughts, very high rainfall variability and sudden and high-intensity rainfall;
(b) poor and highly erodible soils, prone to develop surface crusts;
(c) uneven relief with steep slopes and very diversified landscapes;
(d) extensive forest coverage losses due to frequent wildfires;
(e) crisis conditions in traditional agriculture with associated land abandonment and deterioration of soil and water conservation structures;
(f) unsustainable exploitation of water resources leading to serious environmental damage, including chemical contamination, salinization and exhaustion of aquifers; and
(g) concentration of economic activity in coastal areas as a result of urban growth, industrial activities, tourism and irrigated agriculture.

The Annex IV establishes the general framework of action for the Mediterranean Basin. One very important aspect contained in this Annex is the commitment of the countries affected by desertification processes to develop their own National Plan to Combat Desertification. Another important aspect of the Annex is the reference to the coordination of subregional, regional and joint Action Programmes, and the coordination with other subregions and regions.

PERCEPTION OF DESERTIFICATION

Desertification occurs in the interface of a scientific, an environmental and a socio-economic problem. Some of the scientific and human aspects related to the perception of desertification will be discussed in this section.

The main steps in solving any scientific problem are: analysis, diagnosis, experimentation and application of the generated knowledge. In the case of desertification, the analysis-diagnosis phase has been biased because of the, until recently, lack of perception and sensibility. However this has not been the case in the drylands of the Third World, where people perceive directly the multiples impacts of desertification over their essential resources for subsistence.

The European situation is by far less dramatic but even Western civilisation has historical antecedents of awareness from the very beginning of Mediterranean civilisations; and it has been only recently that this concern has reached the general public and the policy makers. Previously desertification from the European perspective was seen more like an African or Third World problem than a problem of developed countries.

How it has evolved over time is explained with more detail elsewhere (Rubio, 1995). The Stockholm Conference (Council of Europe, 1972), the Earth Summit (UNCED, 1992b), the Convention to Combat Desertification (UNCED, 1994) and the Johannesburg Conference in 2002 can all be seen as land marks in this recent movement to a better visualisation of environmental problems including desertification implications at the European scale, that will help in the continuous processes of better scientific knowledge and diagnosis.

During the last decades it is clear that the transmission of the concern on the deterioration of sensitive drylands does not seem to have been properly exposed. One of the circumstances is that from the beginning the issue was approached with no clear delimitations with other different issues like problems of development, political interest, natural versus anthropogenic processes, etc.

There are also intrinsic difficulties in the diagnosis exercise because of the multifactorial, multiscale and multidisciplinary nature of desertification (Figure 1), and also because of the existence of different processes acting with strong variability in time and space. To complicate things more there is a general lack of adequate data to quantify many processes involved.

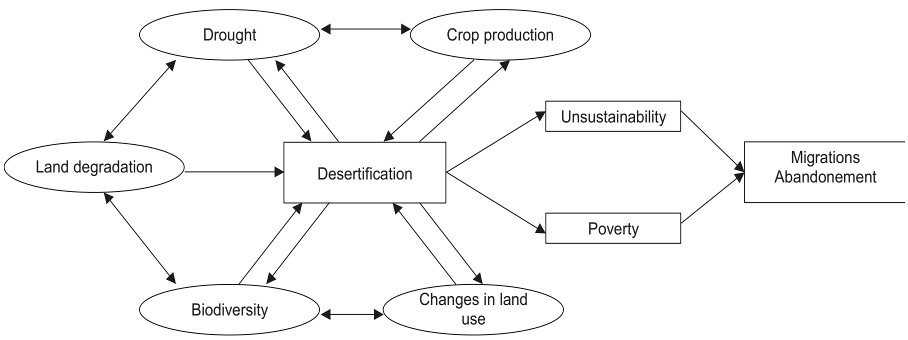

Figure 1. Multifactorial, multiscale and multidisciplinary nature of desertification

Another difficulty is the interactions and implications of socio-economic or human attitudes with biophysical processes, which still lack adequate integrated methodologies for appraisal.

Also the concept of desertification has been sometimes linked to other concepts like drought, aridity, and deforestation. These issues are sometimes confused with the concept of desertification and therefore hinder its clarification and analysis.

At the social level, people affected by the consequences of desertification are usually rural, sometimes isolated, with generally low educational level and not much potential to exert pressure over administrative bodies or policy makers.

The above are some of the circumstances explaining the slow growth of European's consciousness and awareness of desertification processes and their consequences.

EVALUATING DESERTIFICATION

Up to now in the European context, there is no specific assessment of the dimension and scope of the areas affected by desertification risk. This lack of adequate information on the present state of the problem and on its predictable evolution makes it difficult to establish specific measures to fight against desertification. Existing information is either incomplete or is centred in the assessment of desertification at a world wide level, with focus to the undeveloped countries. There are, in general, many local and qualitative observations but very few are quantified and comparable. In this section a revision of published literature on the scope of desertification at global and European level, and the process of water erosion in the Mediterranean regions is presented, with special regard to the methodologies used to assess the desertification processes. This review is an update of a preliminary revision (Rubio, 1991).

The first important approach to the assessment of present and potential desertification, which sounded the alarm world wide on the importance of the problem, was the methodology developed by FAO, UNEP, UNESCO and WMO (1977). These organisations published in 1977 the World Map of Desertification Risk at scale 1:25 000 000. This map is the first assessment of the problem at a global scale and in a homogeneous way, summarising the information available at that time. The methodology used in the compilation of the map was based on a subjective assessment of desertification risks, using bioclimatic, land inherent vulnerability, and human and animal pressure criteria. A map of aridity zones prepared by the UNESCO with data from more than 1200 climatic stations provided by the WMO (World Meteorological Organisation) was used. The limits of the aridity zones (hyper-arid, arid, semi-arid and sub-humid) were obtained from the ratio between the mean annual precipitation and the evapotranspiration. Information on soils was obtained from the Soil Map of the World at scale 1:5 000 000 (FAO, 1974) and data on vegetation from UNESCO's Vegetation Map of the Mediterranean Region and from Schmithusen World Map of Vegetation. Human and animal pressure were assessed from population density data. Four types of land vulnerability to desertification indicators were used: areas affected by sand movements; areas with high proportion of surface stoniness or with generalised rocky outcrops; areas with intense processes of water erosion; and areas affected by salinization and alkalinization processes. Three risk levels were established: very high, high and moderate, so that in the map the geographic extension of each level was represented. The map estimates a high desertification risk for the Spanish Mediterranean zone, and moderate in other points of the Iberian Peninsula and also in the Southern parts of the former USSR. In the rest of Europe there is no desertification risk shown in the map. This first appraisal of desertification is an approximate and global approach that does not include important factors such as forest fires or the abandonment of croplands, factors that have been aggravated since the publication of the map, and that affect especially to the Spanish Mediterranean region, as indicated by Rubio (1987; 1991) and Sanroque *et al*. (1985).

The antecedents of the above World Desertification Map are briefly explained in the following paragraphs.

FAO, UNEP and UNESCO, in their project "World Assessment of Soil Degradation: Phase I", launched in 1975, developed a methodology to assess the global extent of soil degradation. This methodology was used to compile maps of the state and risk of soil degradation in North Africa, the Equator and the Middle Orient. The methodology was then extended, and published as "A Provisional Methodology for Soil Degradation Assessment" (FAO, UNEP and UNESCO, 1980), thought to be used to assess soil degradation at a global scale and at other different scales. Soil degradation processes included in this methodology are: water erosion (divided in sheet and rill erosion, gully erosion, and mass movement); wind erosion; excess of salts (divided into salinization and sodification); chemical degradation (both acidification and toxicity); physical degradation; and biologic degradation. The information was extracted from direct observations, remote sensing images, and observations of the factors affecting degradation and assessed using a simple mathematical model.

In the FAO, UNEP and UNESCO methodologies (1980), two types of assessment of degradation processes are established: present state and risk of degradation. Present state of degradation is expressed as an annual rate indicating the intensity of the process and not the accumulated damage from the past to the present. The risk is calculated for the worst possible conditions of land use, vegetation and management. In 1984, FAO published directives for the control of Soil Degradation (FAO and UNEP, 1984a). In this publication FAO warns about the danger of soil degradation and advises the authorities of those countries affected by this problem the measures that must be adopted to fight degradation.

In the same year, FAO and UNEP (FAO and UNEP, 1984b) published the Provisional Methodology for the Assessment and Cartographic Representation of Desertification. Whereas the methodology formerly described was intended to assess degradation processes, this methodology is centred strictly on desertification soil/land aspects. The processes considered are: degradation of vegetation cover, water erosion, wind erosion, salinization, soil crusting and sealing, decrease of organic matter and accumulation of toxic substances for animals or plants. The three first processes are considered determinative or principal because their effects are more widespread or because of their greater impact, while the other three are considered subordinated. Three aspects of desertification are considered: its present state, the velocity or rate of its progress, and the inherent risk of desertification.

Another important global assessment of soil degradation is the one proposed by Dudal (1982) which has a very synthetic format.

FAO, UNEP, UNESCO and WMO published in 1984 a World Map of Desertification Hazards of the African Continent, at a scale of 1:5 000 000 (UNEP and FAO 1983; 1984), using a methodology more suitable for the conditions of this continent than in global approaches. Together with this map of the world at a scale of 1:10 000 000, a map of the soil units used in the assessment of soil degradation and desertification was published. The data were stored in a database linked to a Geographic Information System (GIS). In this context UNEP published in 1989 several works on the state of desertification and the measures taken to fight it in Southern Africa.

In 1990, the International Soil Reference and Information Centre (ISRIC) and the United Nations Environment Programme (UNEP) edited a World Map of the Status of Human-Induced Soil Degradation in the frame of the GLASOD (Global Assessment of Soil Degradation) project at a scale of 1:10 000 000 (Oldeman *et al*. 1991). The aim of this project was to compile a quality world map of desertification based on the SOTER database (FAO, ISRIC, UNEP and ISSS, 1996). Twelve soil desertification processes were considered, grouped in four main processes: water erosion (soil surface loss and mass movements), wind erosion (soil surface loss, terrain deformation and material deposition by wind), chemical degradation (loss of nutrients and organic matter, salinization, acidification and pollution), and physical degradation (flooding and subsidence of organic soils). Four levels of the degree of the degradation processes were established (light, moderate, strong and extreme), and five types of relative extent of the degradation process inside a soil unit (infrequent, common, frequent, very frequent and dominant). The severity of soil degradation was computed according to the degree and relative extent of a soil degradation process. The human causative factors that induced the degradation were also indicated. The map of the GLASOD project allows a comparison among continents attending to the different land uses.

UNEP published in 1992 a World Atlas of Desertification (UNEP, 1992). In this Atlas, UNCED, felt that the influence of climatic variability in desertification should be reflected. Different approaches to the problem of desertification are provided for the different scales: global, continental (Africa), and local. Global data from UNEP databases, from remote sensing databases, and from bioclimatic databases and soil information from the GLASOD project are used. These data are used to establish an aridity index (mean annual precipitation/mean annual evapotranspiration calculated from the Thornthwaite index). This global vision of desertification processes is completed with an analysis at a continental scale (Africa), and numerous case studies at local scale (in Syria, China, Argentina, Kenya, Mali, Tunisia and Russia).

Besides these works at a global scale, some other appraisal of desertification at European scale can be found. Amongst these studies, Dregne (1983) in an evaluation of drylands, considers that the desertification processes in Europe were only of moderate or great importance in Spain, the most important causes being deforestation, loss of soil fertility, the effect of droughts, the erosion processes and salination in irrigated croplands. Zachar (1982) provided a wide evaluation of erosion in many countries of the Mediterranean Europe, detailing in each country the most important erosive processes and the extension of land affected by erosion. Lal (1990) indicates the great importance of erosion in some European countries, like Greece, Spain, Cyprus or Mediterranean France. The land degradation assessment of Barrow (1991) is also important.

Barrow issues a warning specifically for desertification in Spain, Portugal and Italy.

Various European initiatives to assess desertification in a European scope are reflected in publications such as Desertification in Europe, edited by Fantechi and Margaris (1984), Strategies to Combat Desertification in Mediterranean Europe, edited by Rubio and Rickson (1990), and Desertification in a European Context, edited by Fantechi, Balabanis and Rubio (1995)

In this last publication numerous studies about desertification in Europe are presented. Yassoglou (1995) describes the systems that form the land, and under which conditions these systems interact resulting in land desertification. Bolle (1995) analyses how climatic variability affects surface conditions so that these changes together with man-induced pressures produce, in turn, a change in climatic conditions, and the way in which all this related with the acceleration of desertification processes. The physical, chemical and biological degradation of soil are studied by Imeson (1995). The relationship between desertification and the vegetative cover is analysed by Thornes (1995) and Stamou (1995). It is also worth mentioning the analysis of the methods for the assessment of sustainable use of land by de la Rosa (1995).

Many other studies about desertification or land degradation at global scale and also at a European scale, are centred on water erosion, because this is one of the most important desertification processes, especially in the Mediterranean regions of Europe.

Since the appearance of the USLE (Universal Soil Loss Equation, Wischmeier and Smith, 1978) many other erosion models have been developed from this equation, like the RUSLE (Revised Universal Soil Loss Equation) (Renard *et al*. 1991), the MUSLE equation, which predicts erosion produced by a single rainfall event, or the DUSLE equation, which is the same as the USLE, but adapted to the conditions of Central Europe.

At a European level, there are design studies that deal with the assessment and construction of water erosion models suitable for the Mediterranean Europe. Rubio *et al*. (1984) proposed a methodology to assess water erosion in Mediterranean soils, using the USLE and evaluating new erosion forms not included in the USLE equation. Rubio and Sanroque (1990) analysed the relationship between erosion and desertification in Mediterranean Spain. The creation of water erosion models has also been the objective of many European-wide initiatives, like the CORINE, EUROSEM, EFEDA, MEDALUS and DeMon projects.

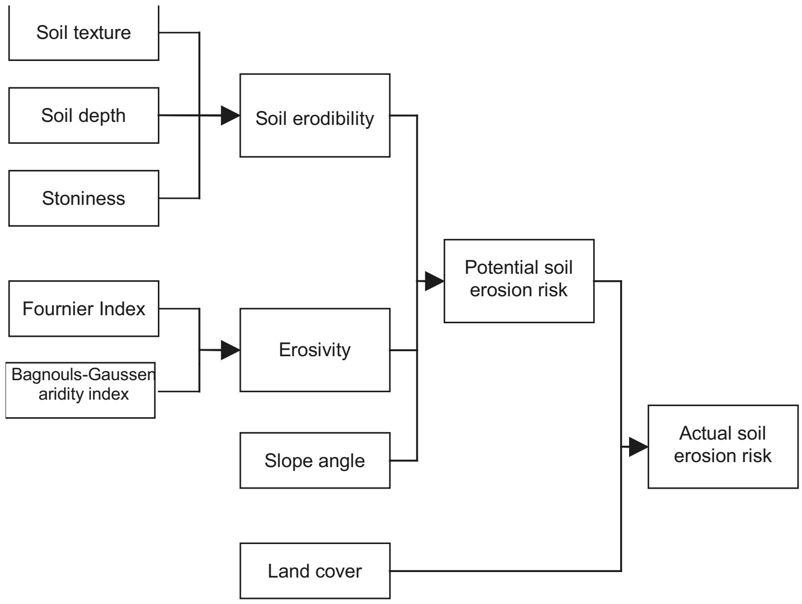

Figure 2. CORINE soil erosion risk assessment methodology

As a consequence of the increasing concern about erosion, especially for the Southern regions of the Community, an assessment of actual and potential soil erosion in southern Community countries (Spain, Portugal, Greece, Italy, South of France) was included within the CORINE programme (1990; 1992). Data existing in those countries were gathered and integrated in a Geographic Information System, and a methodology for assessing soil erosion was developed, maps were produced, and the quality of results was evaluated. The methodology used for assessing soil erosion risk was based on USLE principles. But as the USLE equation is specifically developed for the United States, for local scale, and because it requires more data than that available at the Community level at that time, the USLE methodology was modified. The structure of the resulting methodology is presented in Figure 2. It is shown that the calculus of soil erosion risk involves the calculus of four different indices:

1. Soil erodibility index, obtained using data on texture, soil depth and stoniness.
2. Rainfall erosivity obtained using Fournier index and Bagnouls-Gaussen aridity index.
3. Slope angle
4. Land cover.

This methodology is a qualitative and not a quantitative approach, and therefore the primary data (texture, soil depth, stoniness, slope angle and land cover), are grouped in two, three or four classes.

The methodology used in CORINE for assessing soil erosion risk was highly limited by the shortage and limited homogeneity of data gathered from the different member countries. A similar methodology was developed to assess land quality (CORINE, 1992).

The EUROSEM (European Soil Erosion Model) project (Morgan *et al*., 1993) is the result of the joint work of twenty-five scientists from ten European countries. This project was financed by the Directorate General XII (DG XII) of the Commission of the European Communities. The goal of the project was the construction of a water erosion model adapted to the conditions of the European lands. As a result, the EUROSEM model is a physically based model that describes the processes that produce soil loss after a rainfall event. It predicts soil loss risk and the effects of conservation measures in homogeneous fields and in small catchments. The fraction of rainfall intercepted by canopy is considered in the model, as well as the water that falls from the leaves or flows through the stem. It calculates the volume of water storage in surface depressions, as well as surface runoff, particle detachment by splash and by surface flow. It also calculates the transport capacity of the flow, deposition and sedimentation. It simulates the deposition of material even when the transport capacity is not reached, and explicitly models rill and inter-rill erosion and sediment transport from inter-rill to rill zones.

The Commission of the European Communities (DG XII) and members of the European research community jointly developed the European International Project on Climatic and Hydrological Interactions between the Vegetation, the Atmosphere and the Land surface (ECHIVAL), as a major component of the European Programme on Climate and Natural Hazards (EPOCH). The ECHIVAL Field Experiment in a Desertification-threatened Area (EFEDA) was the first major activity within this project (Bolle *et al*., 1993). An essential aspect of this research project was to investigate how to incorporate experimental results obtained at relatively small sites into mesoscale and global models, which have much larger scale meshes. Satellite measurements were considered to provide a potential bridge between global models and ground-based observations.

The main objective of the MEDALUS (Mediterranean Desertification and Land Use) project, as described by Thornes and Mariota (1995), is the study of the climatic and physic conditions of Mediterranean Europe, the use of remote sensing for the identification of lithologies, vegetative covers and land uses, field investigations and the study of socio-economic aspects related to erosive and desertification processes. Of great importance is the MEDALUS erosion model developed by Kirkby *et al*. (1993). It is a physically based model that provides a mathematical description of the erosive processes in a slope-catena. The model is divided into four sub-models that interact with each other: the atmospheric model, the vegetation model, the surface model (simulates infiltration, surface flow and erosion), and the soil model (simulates subsurface movement of water and the change in the physical properties as a consequence of the erosion and the addition, mixture and decomposition of the organic matter). Other studies in the framework of the MEDALUS project were those by Greppi (1995) in the mathematical description of water erosive processes, by Niedda *et al*. (1995) in the application of the USLE equation to the prediction of soil losses in a catchment, by Poesen (1995) in the description of the determinative factors in soil erosion, and the investigations by Boer (1994a; 1994b) into the estimation of soil humidity and potential erosion using a minimum data set (precipitation, topography) and with a methodology easily linked to a GIS.

Another European initiative in the area of desertification is the DeMon project, launched by the former Institute for Remote Sensing Applications (IRSA), now the Space Applications Institute (SAI), dependant of the Joint Research Centre (JRC, European Commission, Ispra, Italy). The main objective of the DeMon project (Mainguet, (1996) has been to combine the experience of various geoscientific disciplines in order to achieve a common approach to the assessment and control of the degradation and desertification processes in the Mediterranean basin. One of the most important issues in the project has been the use of Remote Sensing data and Geographic Information Systems in the assessment and control of desertification at a regional scale. Regarding water erosion, this desertification process is assessed at two different scales, using a different erosion model for each scale. At the regional scale (approximately 1:100 000), the SEMMED (Soil Erosion Model for Mediterranean Regions) is used, and, the ARSEM (Ardeche Soil Erosion Model) is used at the local or catchment scale (approximately 1:10 000). SEMMED is an empirical model, with a modular structure, so that each module describes a particular set of the erosion processes. Other approach to assessing soil erosion at European level has been developed by the Spanish System of Soil Information in the Internet (SEIS), within the framework of a convention between CSIC (IRNAS and CIDE) and the Ministry of Environment to complement activities on soil studies sponsored by the European Environment Agency (EEA). In 1999, SEIS published several maps of soil degradation on the Internet, including a map of soil erosion, obtained through information sources such as ICONA and ISRIC (Sánchez *et al*., 2001).

The PESERA project (Pan-European Soil Erosion Risk Assessment) is another recent attempt to assess soil erosion in Europe. This project was funded by the European Commission under the V Framework Programme (1998-2002). The three main objectives of the project were: (1) to develop a physical based model to assess soil erosion and identify the most vulnerable areas at European scale, (2) to validate the model in different agro-ecological zones and to compare the results with those obtained by other models such as USLE and CORINE, and (3) to provide an effective tool to improve the decision making process, concerning the evaluation of impacts of soil loss by erosion at European level. The PESERA model, which is qualitative and takes into account the influence of climatic change and land use changes on the erosion process, is now in the calibration and validation phase (Feliu and Gueorguíeva, 2003).

EUROPEAN SCOPE

The Desertification World Map which resulted from the UN Conference held in Nairobi in 1977 provided a synthesis of the information available at that time and represented the first homogeneous, global evaluation of the Desertification issue. As far as Europe was concerned, there was only one area under desertification risk (see Figure 3, which is a partial reproduction of the 1977 UNEP map). This area includes the Iberian Peninsula. Specifically, the unique European area identified having “high desertification risk” was a large part of the Spanish Mediterranean coastline. Areas of “moderate risk” were also pointed out in the map and comprised a zone located in the south of Portugal. Water erosion and salinisation (letters V and S in Figure 3) were identified as the main degradation processes acting in the Spanish and Portuguese areas susceptible to desertification. In the high risk area, human pressure was also indicated (letter H) as being one of the main causes unleashing the threat. No other areas were identified in the rest of Europe, except for broad zones in the south of the former USSR which were classified as "moderate" or "high risk". Erosion and salinisation processes were also the most important causes of desertification in these areas.

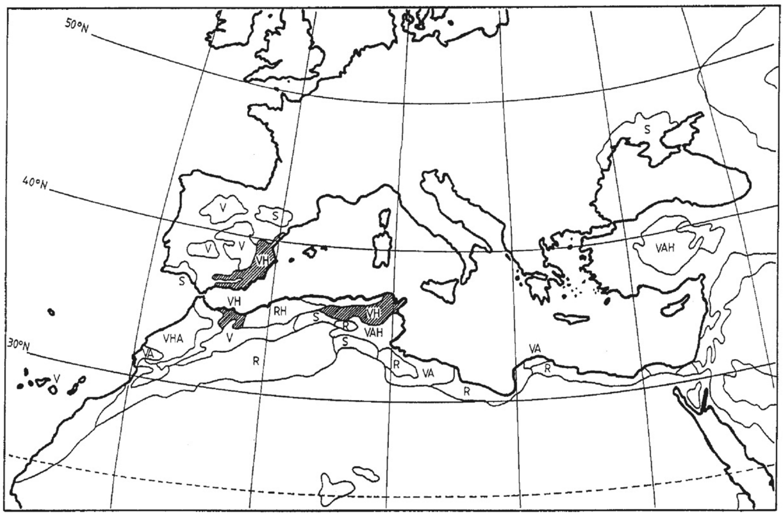

Figure 3. Partial reproduction of the World Map of Risk of Desertification (FAO/UNESCO/OMM, 1977)

Emphasis must be placed on the global and approximate nature of these evaluations (derived from the small working scale), which in addition, ignore areas of Europe and others continents that also display serious problems of degradation. Furthermore, it must also be stressed that the predictions made for Spain probably underestimated the actual and current desertification risk in the country because some of the major factors causing desertification have intensively increased since this early prediction. For instance, after a turning point in 1978 in Spain, the number of forest fires increased from an average of 2 000 in 1977 to about 20 000 fires in 1986 (ICONA, 1986).

The land abandonment of marginal agricultural areas (due to the industrialisation process occurred in Europe in the 1950s-60s and to the premises of the CAP Reform) located on hillsides and the consequent abandonment of soil conservation practices must be also mentioned as a main factor leading to desertification. Breaking up bench terraces and other structures of soil conservation gives rise to intense soil erosion, which can achieve spectacular magnitudes when torrential rainfalls such as the events in the Valencia Region (Spain) in 1982 and 1987 occur.

The Spanish trends toward increasing land degradation processes discussed above may be similarly applicable in other Mediterranean countries.

Many assessments and studies have been carried out on the basis of this first global evaluation, but nevertheless they also referred to the desertification issue in global and synthetic terms, including directly or indirectly the situation of the European countries. As an example, some of these surveys are discussed as follows.

H.E. Dregne realised an assessment of the desertification impact on Europe in his work "Desertification of Arid Lands" (Dregne, 1983). As it can be seen in Figure 4, this study was only focused in Spain and estimated the total area affected by desertification processes to be about 200 000 Km^2. Deforestation, loss of soil fertility, the effects of droughts, erosion processes and salinisation in irrigated agricultural areas were considered the main causes triggering desertification in the study area.

As a consequence of the criticisms made with regard to the accuracy of the data provided by UNCOD (1977), a reassessment of the status and trend of worldwide desertification processes was published in 1984 (Mabbutt, 1984). This study pointed out that the land significantly affected by desertification processes included 75% of the world's arid and semi-arid regions and that 30% of these regions could be considered seriously affected by desertification processes. Concerning Mediterranean Europe, 30% of waste and abandoned land, 32% of rainfed agricultural and 25% of irrigated agricultural areas were classified to be at least moderately desertified. These figures are equivalent to 15, 13 and 1.6 million hectares respectively. In global terms, for the Mediterranean's 30 million hectares of semi-arid drylands, it was estimated that 30% of the total land area was affected by desertification processes.

As commented before, in 1990, the International Soil Reference and Information Centre (ISRIC) together with the UNEP, published a World Map of the Status of Soil Degradation Induced by Man (GLASOD) on a 1:10 million scale. This map allowed comparisons to be made between continents regarding their different soil uses. In the case of irrigated agriculture, the continent with the largest degraded land area was Asia followed gradually by North America, Europe, Africa, South America and Australia.

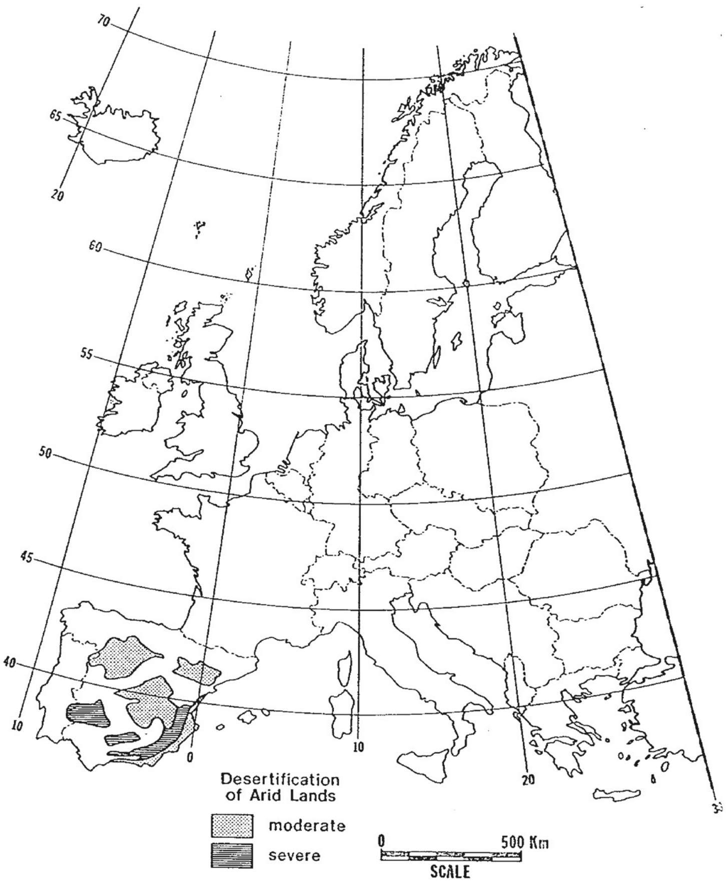

Figure 4. Desertification status in European arid areas (Dregne, 1983)

In "A new Assessment of the World Status of Desertification", Dregne *et al*. (1991) published comparative figures on the extension of desertification on the different continents as a function of land use. Considering the total of arid, semi-arid and dry sub-humid agricultural regions (estimated in 145.18 M. hectares for Europe) it was pointed out that a total of 94.28 M. hectares (equivalent to 64.8%) were affected by degradation-desertification. Annual losses in Europe as a result of these processes were estimated at 1,488 M. hectares. These authors concluded that desertification processes had not yet been attenuated and even continued spreading despite 14 years of efforts by the UNCOD (1977). They therefore considered that the efforts made until that moment had been too modest and, in addition, mistaken to be effective.

The World Desertification Atlas (UNEP, 1992) introduces the new conceptual orientation on desertification (UNEP, 1991) as has been mentioned before in this paper. This Atlas stresses the lack of concrete data on desertification processes, on the highly diverse manifestations of the process and also on the need, as a consequence of the previous aspects, to adopt new approaches to asses the problem. Specifically, desertification indicators and factors affecting them, data from different Geographic Information Systems (GIS) on a world scale connected to UNEP data bases, remote control technologies, bioclimatic data banks, information of soil from the GLASOD and help from expert systems were used in drawing the Atlas.

The Atlas presents a wide variety of maps, including a world map of areas affected by soil degradation, a map of soil susceptibility to degradation under dry climates (drylands), soil erosion and wind erosion maps, maps of chemical and physical degradation and a further combined map of soil degradation and vegetation.

Figure 5 is a partial reproduction of the European soil degradation map showing five ranks of degradation (not degraded, low, medium, high, and very high).

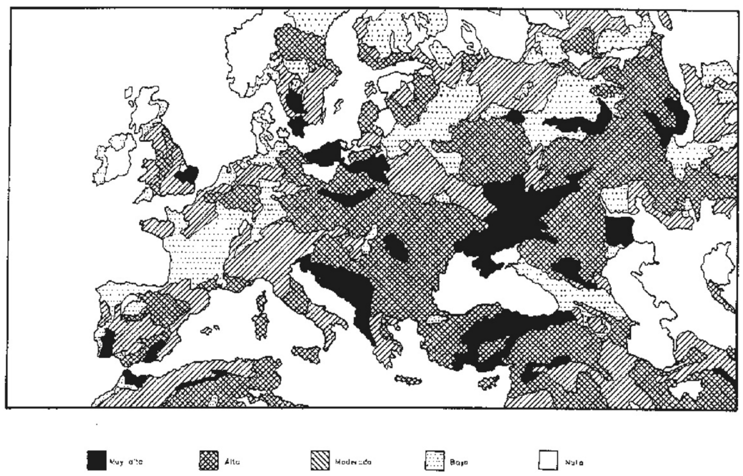

Figure 5. Partial reproduction of soil degradation from the World Atlas of Desertification (UNEP, 1992)

Each of the Atlas´s maps includes an explanatory description (concepts, methodologies, interpretation, map reading, outstanding features) and numerous data in tabular form. This Atlas is a major source of global updated information on the problems of world desertification. Tables 1 and 2 contain information referred to the extension of the different degrees of the degradation-desertification process in the arid, semi-arid and dry sub-humid lands of the different continents as a function of their degree of susceptibility to the process. Considering this information, it can be seen that Europe has the largest area of drylands susceptible to degradation. Specifically, 33% of the European dryland areas are under desertification risk. The Atlas indicates that these areas are located in Spain, Sicily, Greece, and the former USSR. The Atlas also includes the areas affected by soil degradation for the different continents, specifying the main factors causing degradation processes.

Although several models for evaluating desertification have been proposed during the last decades, and have been outlined in this paper, there is still a need to develop new methodologies for properly evaluating the factors, causes and effects of desertification processes in a European context.

Table 1. Soil degradation stage per continents; in drylands (susceptibility) and in others, in Million hectares (UNEP, 1992)

Continent		Light	Moderate	Strong	Extreme	Total degraded	Total Non-degraded	Total
Africa	Susceptible	118.0	127.2	70.7	3.5	319.4	966.6	1286.0
	Others	55.7	64.6	52.8	1.7	174.8	1504.8	1679.6
Asia	Susceptible	156.7	170.1	43.0	0.5	370.3	1301.5	1671.8
	Others	137.8	174.2	64.6	0.0	376.6	2207.6	2584.2
Australasia	Susceptible	83.6	2.4	1.1	0.4	87.5	575.8	663.3
	Others	13.0	1.6	0.8	0.0	15.4	203.5	218.9
Europe	Susceptible	13.8	80.7	1.8	3.1	99.4	200.3	299.7
	Others	46.7	63.8	8.9	0.0	119.4	531.4	650.8
N. America	Susceptible	13.4	58.8	7.3	0.0	79.5	652.9	732.4
	Others	5.5	53.7	19.5	0.0	78.7	1379.8	1458.5
S. America	Susceptible	41.8	31.1	6.2	0.0	79.1	436.9	516.0
	Others	63.0	82.4	18.9	0.0	164.3	1087.2	1251.5
World	Susceptible	427.3	470.3	130.1	7.5	1035.2	4134.0	5169.2
	Others	321.7	440.3	165.5	1.7	929.2	6914.3	7843.5
Total		749.0	910.6	295.6	9.2	1964.4	11084.3	13012.7

Table 2. Degree of soil degradation in arid and semiarid zones, in Million ha (UNEP, 1992)

CONTINENT	Aridity Zone	Light and Moderate	Stong and Extreme	Total
Africa	Dry subhumid	25.2	12.1	37.3
	Semiarid	69.9	39.6	109.5
	Arid	150.2	22.3	172.5
Asia	Dry subhumid	70.6	7.7	78.3
	Semiarid	124.2	17.2	141.4
	Arid	131.9	18.8	150.7
Australasia	Dry subhumid	4.2	0.6	4.8
	Semiarid	32.9	1.0	33.9
	Arid	48.9	0.0	48.9
Europe	Dry subhumid	59.0	2.3	61.3
	Semiarid	30.8	2.6	33.4
	Arid	4.8	0.0	4.8
N. America	Dry subhumid	15.0	3.2	18.2
	Semiarid	50.9	2.3	53.2
	Arid	6.3	1.6	7.9
S. America	Dry subhunid	21.4	2.3	23.7
	Semiarid	43.9	4.0	47.9
	Arid	7.5	0.0	7.5
TOTAL		897.6	133.7	1035.2

DESERTIFICATION VERSUS SECURITY

In the last third of the past century the international agenda on security was progressively expanded to include new aspects, beyond the military. This new trend has initiated some important consequences at the level of individual nations and also at the level of international relationships. At the first level, governments have been made aware of the need to deal with issues such as environment and food security. At the global level, an expanded agenda creates a new and universal paradigm on security to which all the nations will orientate as a positive global aspiration (Buzan, 1998).

The extended concept of security as proposed by Buzan includes five sectors, the military, the political, the economic, the social and the environmental (Table 3).

Table 3. The five security sectors. (Modified from Buzan, 1998).

SECTOR	**ACTORS**
Military	The all society
Political	Governments, administrative bodies, official representatives, …
Economic	Enterprises, banks, corporations, …
Societal	Civil society, associations, …
Environmental	The all society

The sector on societal security includes aspects which are a menace to society but also includes some elements with environmental implications. These are: migrations (closely related to desertification), horizontal competition (for market, natural resources and cultural identities), and vertical competition (which includes the conflict of keeping the nations own traditions on managing the natural resources in competition with more integrated or global approaches).

However, for the purpose of our paper, the closest relation to desertification as a security issue comes mainly from the environmental sector. Previously this sector was focused on topics related to natural disasters such as earthquakes, volcanic eruptions, hurricanes, flooding, tsunamis, etc. However, considering the dramatic consequences of desertification, including the collapse of the ecological and productive functions of the land, it is clear that desertification deserves special attention as a security issue. Some of the consequences of desertification are: direct menace to the all biospheric potential of the affected area; severe alteration of the hydrological cycle with reduction of infiltration and increase of runoff volume and runoff energy; loss of the potential of the soil as a CO_2 regulating system and agricultural and forest production decrease.

These are consequences related to the general functioning of terrestrial ecosystems, but in addition desertification affects some characteristics of drylands which are directly related to security. Those are summarized in Table 4. Particularly, the reduction of soil fertility and the productivity of the land have a direct consequence on food security, mainly in countries with subsistence regimens or which are strongly based on agricultural production. The security of persons, houses, industries and other economic infrastructures are affected by indirect consequences of desertification processes as much as death and loss of property caused by forest fires, intensification of the energy and consequences of severe flooding, and landslides.

Table 4. Desertification and environmental security

CONSEQUENCES
Water scarcity and/or water contamination
Reduction of agricultural food production
Increase of flooding consequences
Vulnerability to effects of droughts
Increase of forest fires and their consequences
Susceptibility to severe landslides and slope collapse
Rupture of the ecological functions of the land

There are also consequences for security related to human migration resulting from the impact of desertification. Particularly in some countries on the southern Mediterranean, the impacts of desertification, drought and death have created severe famine situations due to the failure of agriculture and livestock production, and diminished water resources. These are important factors contributing to an increase in the migratory movements of people from Africa to Europe. Besides that, the difference in economic income between Europe and the Magreb is 1 to 15, which is the largest difference across any international border in the world. This difference is, for example, double the one existing between Mexico and the USA, and it is estimated that 7 million of the inhabitants of the EU are migrants from the shores of the southern Mediterranean.

There is also a link between desertification and societal security in the context of border conflicts owing to illegal migrations which cause political instability, deaths and civil pressure in the border areas. Once the migratory population is established in the country of reception they sometimes create conflicts about labour issues with the administration, companies and the local labour force.

Potential conflicts may also arise because of the difficulties of integration due to differences in cultural and religious background.

Very closely related to personal security is the situation derived from illegal emigrants with no source of income, which unfortunately could in some cases create civil security problems.

For the reasons discussed above, the concept of security should be expanded again to include desertification (a biophysical process with strong socio-economic connotations), as one of the most important security threats originating in dryland ecosystems but with the potential to affect other climatic and economic zones of the World.

PERSPECTIVES

- Desertification is a crucial and increasing environmental issue today in Europe that requires important attention and efforts for its control and mitigation. At global level, Europe has the largest area of drylands susceptible to desertification. Desertification processes, ranging from high to low intensity, affect approximately 10 per cent of the total European land area. Specifically, the European Mediterranean Region is particularly sensitive to desertification processes due to fragile environmental conditions (UNCCD, Annex IV).
- A primarily effort for undertaking the desertification issue refers to the need for achieving relevant information about desertification processes and their environmental implications, including security issues. Numerous assessments and studies, including those in Europe, have been made on the basis of a first and preliminary global evaluation of desertification. However, at the present time there is no concrete, specific information of the extent and scope of European areas under risk of desertification, and therefore no serious and scientific assessment of the issue. There is a need for an adequate desertification evaluation which includes, among other aspects, a detailed characterisation of the European sites threatened by desertification processes. The joint co-operation and collaboration of the European organizations and institutions dealing with the appraisal of Desertification in Europe (e.g. EU, EEA, EP, ESB, ETC/TE, ENRICH, ISRIC, TERI, NATO, etc.) are essential for producing this first evaluation and also for providing further information concerning the desertification issue in Europe. For the elaboration of this information it is necessary to determine the main factors, causes and effects of the desertification processes and to gain better understanding of the links between them.
- The main factors and causes of desertification processes acting in Europe are biophysical, socio-economic and historical aspects. They are the following: dry climate (e.g. recurrence of droughts, seasonal torrential rainfall), geomorphology favouring soil erosion processes, quantitative and qualitative alterations of the water balance, over-exploitation of superficial and underground water resources,

inappropriate land use changes, deforestation, increasing forest fires, agricultural intensification, overgrazing, inadequate forest and agricultural practices, urban and industrial expansion, socio-economic factors such as pressure of the population in certain sensitive areas or human abandonment of agricultural marginal land, tourism, market forces affecting agricultural and forestry production, international regulations on trade, etc. A large part of the current desertification processes are an inheritance from prior historical actions (immediate and remote). The impact and consequences of different former land uses in the Mediterranean can be used to help our understanding of the evolution of the process of desertification towards its present state in the area, and to formulate ways to arrest it's further onset and more widespread development of land degradation and desertification.

- These factors and causes operate in different temporal and spatial contexts influencing the course of the natural processes involved in desertification. It is important to know and characterise the factors and causes acting at each level. At global scale, both natural (mainly atmospheric factors) and socio-economic factors (economical, cultural and political) influence the desertification processes. At regional scale, the factors acting are essentially physiographic, meteorological, economic and cultural aspects, and operate over large areas (e.g. river basins, mountain massifs, coastal zones, etc.). At local scale, specific physiography, soil types and uses, cultural traditions and land management are relevant factors in desertification processes.
- The main effects of desertification processes at European level are the following:

    - severe soil degradation by erosion; contamination (by heavy metals, pesticides and other organic contaminants, nitrates, phosphates and artificial radionucleides); compaction; loss of organic matter through inadequate management practices; salinisation/sodication and waterlogging.
    - reduction of vegetation cover particularly through land transformation, forest fires and soil degradation.
    - quantitative and qualitative depletion of superficial and underground water resources by over-exploitation.
    - deterioration of landscape by the replacement of natural and diverse areas by artificial and uniform areas for cultivation, urbanisation, etc.

- loss of biodiversity directly linked to the loss of habitats due to destruction, modification and fragmentation of ecosystems by intensive farming methods, land urbanisation, etc.

- There are gaps in the existing research on desertification, but however there is also a need to develop new research for acquiring more scientific knowledge on the factors, causes and effects of desertification processes. The collection of data and the development of indicators are crucial for a better understanding of the dynamic and complex processes of desertification. Relevant data are required to validate mathematical models, and to update cartographic documents of the areas affected by desertification processes. It is important to develop new methodologies to study the processes of desertification, and to encourage multi-disciplinary research into the phenomena. Research methodology and results should be standardised to facilitate the transfer of knowledge. Specific experiments should be designed to research into the different aspects of desertification processes. It is necessary to increase scientific information regarding specific Mediterranean conditions. For these purposes, the potential of new information technologies (e.g. remote sensing, modelling, indicators, etc.), and the transfer of information for better assessment and monitoring of desertification processes should be explored.

RECOMMENDATIONS / ACTION PROPOSALS

- The United Nations Convention to Combat Desertification establishes the global dimension of desertification problems and the possibilities of international collaboration. Moreover, desertification of drylands includes aspects of many disciplines (climate, soil, land use, new technologies …), which also offers great possibilities for international co-operation. Specifically, The Regional Implementation Annex for the Northern Mediterranean Region contains guidelines and arrangements to prepare National Action Programmes and sub-regional, regional and joint action programmes by the affected country parties for the effective implementation of the Convention. On the basis provided by this Convention, collaboration and co-operation between European and other international organisations and institutions should be established in order to promote initiatives concerning joint programmes, financial aspects and technology transfer for developing pilot research projects of desertification processes. Institutions such as NATO (CCMS and Committee of Science) should be requested to facilitate the integration of joint efforts directed to face security issues arising from desertification.

- From the knowledge gained and information generated by scientific research, recommendations for combating desertification should be proposed. Policies and strategies for making compatible environmental conservation and economical progress should be developed and be properly implemented. The need for integrating socio-economic (including security issues) and environmental factors must be emphasised in developing recommendations aimed at combating desertification processes. There is an urgent need to devise recommendations for the Mediterranean region taking into account its particular environmental conditions. Particular emphasis should be placed on finding feasible land use alternatives for agricultural marginal areas or for the areas affected by the implementation of the CAP. Studies on the possibilities of utilising autochthony vegetation for conservation and economic return should have high priority in such areas.
- It is important to consider desertification as an issue involving the whole of society. More recognition should be given to the importance and responsibilities of all social sectors involved in the study and control of the desertification processes. Efforts should be made to ensure transfer of ideas and information between these sectors. The scientific community should be encouraged to continue to generate and disseminate information, and to create awareness of the environmental problems associated with land degradation and desertification. Information and environmentally friendly methodologies should be provided to people affected by desertification but specially to those at the local level, who are the most directly affected. It is important to develop regulations at the land owner level that lead to the reorganization of inadequate agro-forestry, urban and recreation uses of the land.
- Action proposals should be developed and implemented to combat desertification. Immediate actions should be recommended on:

  - Integrated land use planning and application of sustainable systems of exploitation of land resources.
  - Rational use and protection of soil, water resources, vegetation, landscape and ecosystems.

- Mitigate the security issues related directly or indirectly to desertification processes.

CONCLUSIONS

Desertification is a crucial and increasing environmental issue in Mediterranean Europe affecting approximately 10% of the total land area.

There is a need for better desertification appraisal and stronger cooperation and coordination between affected European countries, which could be achieved through the potential development of Annex IV of UNCCD.

Desertification processes directly and indirectly affect aspects of Environmental and Societal Security. For mitigating and preventing security issues related to desertification, a better and stronger collaboration is needed between Northern and Southern Mediterranean shores, including also the collaboration with other international organizations.

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PART II

Mediterranean Regional Perspective on Assessment and Condition

("the country reports")

PROBLEMATIQUE DE LA DESERTIFICATION EN ALGERIE: ETAT ET MESURES DE LUTTE POUR LA PROTECTION DES RESSOURCES NATURELLES

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ABSTRACT

Desertification problems in Algeria are defined in terms of development. An examination of natural resources degradation (including soil, vegetation, water), seems to indicate that the principal causes of this phenomenon are principally of human origin. The South Algerian region, including a large part of the Sahara Desert, is already desertified, but this process is also of great concern in the northern regions and as well as on the steppes where more than half of the surface (20 millions of hectares) is threatened by desertification.

Some measures have been undertaken since 1971 to stop this phenomenon through the "Green dam" project done by the young people of the National Army Service, but they still are insufficient.

The acceleration of desertification processes has brought negative socio-economic impacts on affected communities and can be expressed in terms of:

- reduction of forage
- livestock carrying capacity and numbers
- disruption of the pastoral system
- sand encroachmentr of communication infrastructures and of some towns.

A National Action Plan has been developed and it should be validated soon in the framework and implementation of the UN Convention to Combat Desertification.

Besides the classic techniques to fight against desertification (reforestation, erosion control, land improvement, dune fixation, etc…), other techniques are also introduced, principally to evaluate processes, and aided by satellite image interpretation, and through the implementation of regional management schemes.

The fight against desertification is also the fight against poverty and starvation and consequently, it is the fight against insecurity and the decrease of social conflicts.

Desertification in the Mediterranean Region: *a Security Issue,* **169–185.**
William G. Kepner, Jose L. Rubio, David A. Mouat & Fausto Pedrazzini, eds.

SOMMAIRE

INTRODUCTION

Avec 2,4 millions de km2 de superficie, l'Algérie longe d'Est en Ouest la mer Méditerranée sur 1200 km et s'enfonce du Nord au Sud sur plus de 2000 km au cœur même du grand désert du Sahara.

Cet espace important abrite environ 32 millions d'habitants dont la majeur partie (90%) vit dans la partie Nord du pays.

La particularité géo-climatique du territoire national nous amène à considérer trois grands espaces ou écosystèmes.

- L'écosystème montagneux, localisé dans la zone tellienne qui rassemble des chaînes et des chaînons de montagne caractérisés par de sols évolué, calcimagnésique, fersialitiques et bruns constituant une structure fragile soumise à une forte dégradation sous l'effet de l'érosion.
- L'écosystème steppique, défini comme la portion du territoire national délimité au Nord par l'isohyète 400mm et au Sud par l'isohyète 100 mm .Il se caractérise par un sol pauvre avec une prédominance d'une couche dur de calcaire.
- L'écosystème saharien qui occupe prés de 80% de la superficie totale et qui s'étend au sud de l'Atlas Saharien partagé par de grandes unités morphologiques, les ergs sableux, les hamadas (plateaux caillouteux) et le Hoggar est caractérisé par une sécheresse absolue et une salinité prononcée.

Cette phytogéographie variée a engendré une multitude de paysages et de biotopes très riches au plan de la diversité biologique.

En effet, les ressources biologiques sont un élément stratégique dans le développement durable, elles englobent les ressources végétales, animales, et la biodiversité en général.

Le développement durable passe indiscutablement par la sauvegarde de ces ressources et leur développement.

LES SOLS

Occupation actuelle

La majorité de nos sols sont dénudés et portent rarement une couverture végétale protectrice. Même les sols agricoles, par le système de jachère pratiqué au profit de l'élevage sont souvent inoccupés.

Cette pratique les soumet aux risques d'érosion hydrique d'une manière permanente ce qui explique également le volume important de sédiments déversés en mer et dans les barrages.

Mis à part, les sols couvert de végétation de type forestier, tous les autres sont dans un état de dégradation avancée suite aux phénomènes d'érosion hydrique et éolienne auxquels s'ajoutent l'urbanisation des terres potentielles.

Les phénomènes de dégradation

L'érosion hydrique

Les sols soumis aux phénomènes d'érosion hydrique sont particulièrement ceux qui ont une forte pente et situés à des altitudes élevées. Sachant que 68% du territoire national a une altitude moyenne supérieure à 800 m et que 30% des sols ont une pente supérieure à 12%, il est considéré que c'est surtout ces sols qui sont soumis à l'érosion hydrique.

A cela, s'ajoute la torrentialité des pluies, puisque la statistique météorologique enregistre une valeur moyenne de 45 mm de pluie en 24 heures et ce plusieurs fois dans l'année.

Parmi les autres causes, exposants les sols à l'érosion hydrique, on peut citer:

-Les incendies de forêts qui mettent à nu les sols fragiles.

-Les défrichements abusifs pour l'extension de l'agriculture vivrière.

-Les excès de parcours qui provoquent les tassements favorisant le ruissellement et qui empêchent ainsi toute régénération de la végétation.

-Les techniques culturales traditionnelles pratiquées par les agriculteurs dans le sens de la pente et favorisant ainsi le ruissellement et l'érosion des sols.

Toutes ces causes ont pour conséquence, non seulement la perte des éléments fins du sol mais provoquent également des glissements de terrain et des éboulements.

La superficie totale menacée par l'érosion hydrique est estimée à prés de 10 millions d'ha.

D'après les évaluations faites, les pertes en sol seraient de 120 millions de tonnes de sédiments perdues annuellement, soit l'équivalent de 40.000 ha de terres arables.

Les quantifications faites au niveau des bassins-versants montrent que 16,6 m3 de terres par hectare sont érodées annuellement et représentent 1,6 mm d'épaisseur.

D'autres conséquences sont également engendrées par l'érosion hydriques comme notamment la perte des ressources en eau par la non alimentation des nappes phréatiques, suite à la diminution de l'infiltration, l'envasement des barrages dont certains ont atteint un taux de sédimentation qui avoisine les 100% à l'image des barrages de Fergoug,Ksob et Foum-El-Gueiss.

L'érosion éolienne

Ce phénomène très important touche particulièrement les zones arides et semi-arides en général et la steppe en particulier.

Bien que ce phénomène prend au fil des années des proportions alarmantes, à ce jour aucune quantification scientifique n'a pu être faite en Algérie en vue d'apprécier les pertes en sol engendrées par ce phénomène.

Il est à souligner qu'un document de constat initié par l'administration des forêts et élaboré par télédétection donne des résultats inquiétant puisqu'il ressort que prés de 600.000 ha de terres en zone steppique sont totalement désertifiés sans possibilité de remontée biologique et que près de 6 millions d'ha sont très menacés par les effets de l'érosion éolienne.

Cette érosion, résulte d'un déséquilibre dans les interactions dynamiques entre le climat, le sol, la végétation et l'homme. Elle provient des effets conjugués des changements climatiques(sécheresse persistante)et des activités humaines non adaptées, appliquées à des sols fragiles.

Ces activités sont "imposées" par des besoins de plus en plus importants d'une population en constant accroissement ce qui entraîne une extension des zones de mise en culture sur des sols peu propices à l'agriculture d'une part et d'autre part à des zones qui sont traditionnellement réservées à d'autres spéculations à l'exemple des labours réalisés sur les parcours.

La salinisation

Outre, les sols de chotts et sebkhas, les sols agricoles irrigués sont également sujets à une salinisation du fait de la mauvaise qualité des eaux, de l'importance de l'évapotranspiration et des mauvaises conditions de drainage.

Ce phénomène est notamment perçu au niveau des oasis et de certains périmètres agricoles situées dans les zones arides et semi-arides (cas d'Abadla, Relizane ...).

A ce jour, 300.000 ha. de terres sont irrigables sur 1,4 millions d'ha inventoriées, classées et susceptibles d'être irriguées. Cela suppose que les risques de salinisation sont présents si les conditions adéquates de drainage ne sont pas réunies.

Les pollutions chimiques

L'utilisation incontrôlée des engrais et des produits phytosanitaires entraîne souvent la disparition de la micro-faune et de la microflore des sols et par conséquent diminue la fertilité de la couche arable.

Actuellement, il est difficile d'évaluer les superficies touchées par cette pollution faute d'une statistique suivie, mais il est à souligner que ces surfaces sont importantes notamment au niveau des terres à haut potentiel agricole eu égard aux quantités d'engrais importantes utilisées par l'agriculture (plus de 600.000 quintaux par an).

D'autres formes de pollution portent atteinte à la fertilité des sols comme notamment les eaux usées rejetées dans le milieu naturel, ainsi que les décharges incontrôlées situées à proximité des terres agricoles.

Les pratiques culturales

Les pratiques culturales inadaptées entraînent souvent l'érosion du sol notamment par les labours dans le sens de la pente. En effet, les sillons tracés constituent des canaux privilégiés dans lesquels la rapidité d'écoulement des eaux génère une érosion intense.

D'autres pratiques culturales sont également à l'origine de l'érosion des sols telles que la jachère cultivée et l'introduction de la charrue à disques en milieu steppique.

Les superficies labourées annuellement et soumises à l'érosion éolienne sont estimées à prés de 1,2 millions d'ha.

L'urbanisation

L'urbanisation et l'industrialisation se font très souvent sur des terres agricoles les plus fertiles, par le fait que les promoteurs choisissent des solutions de facilité qui ne nécessitent pas des investissements importants dans le domaine du génie civil.

Cette option, négative, continue le plus souvent malgré les multiples cris d'alarme lancés par les associations de protection de l'environnement et les pouvoirs publics qui n'arrivent pas à endiguer ou à maîtriser cette hémorragie des terres fertiles.

Ainsi, les surfaces perdues pour l'activité agricole sont estimées à 250.000 ha dont 10.000 ha en irrigué.

On peut dire qu'en matière de patrimoine sol, la situation est des plus alarmante.

Outre, les phénomènes de dégradation multiples, ajoutés à l'accroissement démographique, la superficie agricole utile par habitant ne fait que régresser.

Ainsi, la statistique nous indique qu'en 1962, la SAU par habitant était de 0,82 ha., en 1982, elle est passée à 0,36 ha puis à 0,32 ha en 1989, elle se rapprocherait actuellement de 0,20 ha/hab.

Ces chiffres montrent bien une situation des plus inquiétante pour l'agriculture algérienne et surtout pour la sécurité alimentaire du pays.

Cela implique que non seulement des efforts importants de protection doivent être déployés mais aussi réfléchir à de nouvelles zones à mettre en valeur pour accroître la superficie agricole, ce qui bien sûr nécessitera des investissements importants.

Il faut rappeler qu'environ 60% de la population totale vivent actuellement sur une bande côtière représentant environ 1,7% de la superficie totale du pays et où sont concentrées la plupart des ressources hydriques, des terres agricoles et des infrastructures industrielles.

La densité de la population dans cette zone est estimée à 233 habitants par km2, alors qu'elle était de 169 hab./km2 en 1977.La pression exercée par cette densité croissante sur les terres les plus productives est un problème préoccupant et ne fait qu'aggraver la dégradation des sols et leur perte à jamais.

Bilan des activités de protection des sols

Les actions engagées pour lutter contre l'érosion des sols en Algérie ont débuté à partir d'expérimentations de techniques de lutte anti-érosive qui pour certaines n'ont pas donné les résultats escomptés.

Les principales opérations réalisées sont la défense et restauration des sols (DRS), la correction torrentielle,l es reboisements et l'amélioration foncière.

La Défense et Restauration des Sols

La défense et restauration des sols est un ensemble d'actions tendant à lutter contre l'érosion des sols et qui a été initié en 1942 par la création du "service de la DRS".

La technique utilisée est celle des banquettes qui consiste à couper à intervalles régulier les pentes les plus fortes par des terrasses sur lesquelles sont plantés des arbres forestiers ou fruitiers rustiques.

En 1964, la superficie totale traitée en 20 ans par cette technique était de 375.000 ha, orientée essentiellement sur la protection des terres de plaines et des barrages afin d'assurer l'essor de l'agriculture coloniale.

En 1984, un bilan a été fait sur les conséquences et les effets induits par cette technique tant sur le plan physique qu'économique.

Il est ressorti que l'ensemble des banquettes réalisées ont beaucoup plus favorisé l'érosion hydrique notamment au niveau des zones dont la structure est instable et du fait que cette méthode a rencontré une forte opposition de la population locale qui détruisaient systématiquement les ouvrages de DRS, ce qui aggrave ainsi la dégradation du sol.

Depuis, cette technique a été abandonnée. Il est probable également que l'une des raisons de l'abondon de cette technique est le coût financier très élevé de l'opération de réalisation et du manque d'entretien de cette infrastructure.

La correction torrentielle

Elle est l'une des techniques de la DRS qui continue à être utilisée du fait qu'elle permet la régulation des eaux torrentielles par la construction de petits barrages successifs et de seuils le long du torrent.

Ces seuils sont le plus souvent réalisés avec de la pierre sèche et maintenus quelque fois dans des gabions. Le volume réalisé à travers le territoire national est estimé à plus de 1 millions de m^3.

Ce volume reste insuffisant eu égard à l'importance des surfaces à traiter et du fait aussi de l'indisponibilité par endroit du matériau nécessaire en l'occurrence la pierre sèche.

Cette opération de correction des torrents est généralement accompagnée d'une protection biologique par la fixation des berges.

Les volumes durant ces dernières années ont tendances à s'intensifier au vu du programme des Grand Travaux qui prévoit la réalisation de 330.000m^3 en trois ans.

Les plantations

La couverture végétale du sol reste l'un des moyens les plus efficaces pour sa protection contre les phénomènes d'érosion.

Ainsi, les actions de reboisements en Algérie ont eu un caractère beaucoup plus de protection que de production.

La superficie plantées depuis l'indépendance est estimée à 1.000.000 d'ha suivant le bilan des programmes planifiés.

Cependant, suivant les enquêtes réalisées sur le terrain et compte tenu des taux de réussite enregistré (50% de la superficie totale a un taux de réussite de 80%, tandis que le reste a un taux de réussite moyen de 40%) la surface réelle boisée est d'environ 600.000 ha.

Ainsi, a superficie reboisée ne représente que 10% de la superficie totale des bassins versants à protéger, alors que le taux nécessaire pour protéger un barrage contre l'envasement est de 25%.

Cela suppose qu'il faudra encore reboiser environ 1.000.000 d'ha pour protéger les bassins versants des barrages en exploitation et en projet.

L'amélioration foncière

Cette opération qui a un effet indirect sur la protection des sols contre les phénomènes d'érosion permet d'encourager les agriculteurs à travailler leur terre et de ce fait d'atténuer les effets d'érosion.

L'opération consiste en des labours profonds nécessitant l'utilisation de bulldozers avec des rooters qui remuent le sol jusqu'à une profondeur de 1,20m.Cette technique permet une bonne infiltration des eaux, tout en augmentant les potentialités productives des sols, donc les rendements. A ce jour, prés de 50.000 ha ont été traités.

LES RESSOURCES VEGETALES

Les ressources végétales naturelles sont caractérisées par trois écosystèmes principaux:

-Les écosystèmes forestiers.

-Les écosystèmes pastoraux.

-Les écosystèmes sahariens.

L'Algérie, avec une superficie de 238 millions d'ha dispose d'une superficie très limitée en couverture forestière.

Avec 4.150.000 ha de forêts, le taux de boisement n'est que de 1,5%.Si nous prenons en considération que les terres sylvatiques, c'est à dire celles du nord, ce taux n'est que de 10%, en comparaison avec le taux nécessaire pour un équilibre écologique et qui est de 20 à 25%.

Cependant, à l'instar de la forêt méditerranéenne, celle-ci est soumise à une dégradation continue sous la pression anthropique et les incendies.

Au niveau steppique, les écosystèmes pastoraux subissent une dégradation persistante et continue notamment la désertification.

Outre, la sécheresse persistante et cyclique, la végétation pastorale malgré sa variété et sa richesse, est soumise à une exploitation de type "minier" qui, a moyen terme, si cette situation persiste, verrait sa disparition totale.

L'alfa, avec 3 millions d'ha, reste la végétation homogène dominante avec l'armoise (4 millions d'ha), le sparte ainsi que le pistachier et le jujubier au niveau des dayas.

La flore du Sahara est dans la plupart des cas au stade relique comme le cyprès du tassili. Nous trouvons ponctuellement des acacias radiana, mais la plus importante reste relativement la flore herbacée évaluée par Ozenda en 1977 à, 500 espèces de plantes vasculaires et 700 espèces de cryptogames.

LES RESSOURCES ANIMALES

Le patrimoine génétique de la faune domestique et sauvage est riche et diversifié. La localisation est tributaire d'une part des pratiques agricoles et des ressources végétales pour la faune domestiques et d'autres part des situations des biotopes naturels pour la faune sauvage.

La faune domestique

La faune domestique est surtout caractérisée par son patrimoine génétique bien adapté aux conditions climatiques du pays particulièrement pour le cheptel ovin. Ce dernier est évalué à 17 millions de têtes dont 50% constitué de race locale Ouled Djellal,30% de race Hamra,15 à 20% de race Rembi. La race D'mina, trés prolifique se concentre notamment au niveau du sud-ouest.

La race bovine quant à elle est estimée à 1,2 millions de têtes localisée à plus de 80% dans les zones tellienne. Ce cheptel est surtout constitué de race Brune de l'Atlas et de Guelma.

Durant la dernière decennie, des importations de races bovine à haut potentiel de production ont eu lieu avec des Pie noire et pie rouge. Ce cheptel importé est estimé entre 200 et 300.000 têtes.

La race caprine, localisée à 70% en zones steppique est évaluée à plus de 2 millions de têtes

Les équins sont constitués de races barbes, pur sang arabe et arabe-barbe. Estimée à 150.000 têtes, le cheptel équin est surtout localisé au niveau des hauts plateaux.

La race asine qui a connu une régression importante est estimée à 450.000 têtes ainsi que la mulassière estimée quant à elle à 200.000 têtes.

Le camelin (dromadaire) compte un troupeau de 100.000 têtes localisé exclusivement en zone sahariennes.

Enfin la basse cour qui a connu un développement spectaculaire ces dernières années grâce aux élevages industriels (volaille, dinde, pintade, oie, canard...).

La faune sauvage

La situation privilégiée de l'Algérie explique la diversité des biotopes qui se succède depuis la zone méditerranéenne jusqu'à la zone saharienne.

Les zones protégées, recèlent d'importantes espèces animales dont le recensement fait ressortir 90 espèces de mammifères, 350 espèces d'oiseaux, 70 espèces de reptiles, 12 espèces d'amphibiens et 70 espèces de poissons d'eau douce.

Outre l'importance des espèces endémiques, les zones humides accueillent d'importantes populations espèces migratrices.

Parmi les espèces disparues ou en voie de disparition des écosystèmes steppiques, on peut citer le lion de l'atlas, l'autruche d'Afrique du nord et celles qui sont en voie d'extinction ou même localement éteintes, il y a l'addax, l'oryx, les gazelles, l e cerf de barbarie, le lynx ,l'outarde.

Cette situation est consécutive à une chasse abusive et leur compétition avec l'homme ou le bétail.

PERSPECTIVES

En matière de sols

L'évolution probable de la situation actuelle de la ressource en sol ira dans un sens relativement régressif pour les raisons suivantes:

-Les pluies torrentielles d'hiver qui interviennent d'une manière cyclique continueront d'être la principale cause d'une érosion importante particulièrement quant les sols perdent leur couverture végétale.

-La sécheresse est elle aussi un risque naturel périodique créant les conditions naturelles à l'érosion des sols.

-Les sols seront marqués également par un contenu élevé en sel et en calcaire conduisant à la salinité.

Cette situation concerne plus particulièrement les nouvelles terres mise en valeur et nécessitant une irrigation. A ce niveau, la nécessité de procéder à la mise en place d'un réseau de drainage pour toute action nouvelle de mise en valeur s'impose dans tous les milieux.

La croissance démographique bien qu'elle s'est ralentie durant la dernière décennie (de 3,2% en 1966-1977 à 2,3%), l'urbanisation continuera à se développer plus particulièrement au niveau des petites et moyennes villes de l'intérieur du pays, du fait que les grands centres urbains ont atteint leur point de saturation.

Si cette situation persiste, il est permis de penser que les pertes en terres agricoles seront plus importantes dans les prochaines années eu égard au déficit en logement du pays et au développement intensif des villes. Si ,jusqu'à ce jour une perte annuelle de plus de 7.000 ha a été enregistrée, à moyen terme, compte tenu des besoins cités plus haut, cette perte pourrait être multipliée par 2 ou 3.

Cette situation ne peut être maîtrisé que par l'instauration:

-D'une politique d'aménagement du territoire rigoureuse et continue à travers l'élaboration de différents plans d'utilisation des sols (PDOS, PDAU).

-L'intensification des activités de lutte contre l'érosion des sols notamment au niveau des bassins versants de barrage et les zones steppiques.

Au niveau des bassins versants, les aménagements doivent être avant tout multisectoriels ou chaque secteur doit assumer sa mission pour assurer un développement globale et harmonieux.

Une prise en charge dynamique des populations doit être entreprise par l'instauration d'un assolement agricole adéquat, la pratique de techniques adaptées et la disponibilité d'un matériel spécialisé.

Ces objectifs ne peuvent être atteint que par une vulgarisation permanente et intensive avec des moyens et méthodes adaptées aux conditions sociologiques de chaque terroir spécifique pour arriver à bout des pratiques traditionnels bien ancrées dans les zones rurales.

La maîtrise de la planification à moyen terme en matière de réalisation de grandes retenues d'eau est nécessaire pour permettre aux services spécialisés de traiter le bassin versant au moins 5 à 10 ans avant la construction de la digue du barrage.

Pour rationaliser ces activités, celles-ci doivent être intégrées dans le cadre d'une stratégie nationale à long terme de lutte contre l'érosion et la désertification (Plans nationaux).

Les ressources végétales

Les incendies de forêts, les labours non contrôlés en steppe,les mauvaises techniques agricoles, le surpâturage et l'introduction anarchiques d'espèces exotiques donnent un tableau très pessimiste quant à l'avenir des ressources végétales si des mesures énergiques de gestion, de préservation et de développement ne sont pas prises.

Dans cette optique, il est nécessaire d'entreprendre les actions suivantes:

-Ite de l'inventaire national de la flore afin de connaître et maîtriser le potentiel existant.

-Détermination des zones fragiles et menacées pour que les dispositions prioritaires soient prises.

-Poursuite des études d'aménagement des forêts et leur application en vue d'abord d'assurer leur pérennité et exploiter d'une manière rationnelle leur produit.

-Intensifier les activités de reboisement notamment dans le cadre du Plan National de Reboisement en cours d'élaboration.

-Poursuivre la diversification des espèces par la sélection et la production de plants de qualité à partir du matériel végétal local. Ceci passe également par la modernisation du réseau pépinière.

-Consolider, la protection des forêts notamment par des moyens adéquats.

-Constitution d'une banque de graines, de jardins botaniques et de stations de conservations et de multiplication des végétaux en vue de leur réintroduction dans leur écosystèmes d'origine.

-Pour la steppe en particulier, l'organisation des agro-pasteurs est impérative pour limiter la dégradation de la végétation.

-Le statut juridique de ces terres semblerait le point essentiel à résoudre pour une future organisation adéquate.

-Intensifier la recherche et l'expérimentation surtout sur les espèces locales pour augmenter leur potentiel productif.

-Disposer de spécialistes (notamment par la formation) pour la prise en charge scientifique et technique du développement et de la protection des ressources végétales (Systématicien, généticien ...).

Les ressources animales

Pour la faune domestique, l'essentiel réside dans la sauvegarde et la sélection des races locales adaptées à notre écosystème.

A cet effet, la création d'un stand de race nationales est une nécessité pour d'abord connaître notre potentiel et l'améliorer ensuite.

Pour cela, il est nécessaire d'établir les priorités de manière à ce qu'elles soient prises en charge par les instituts spécialisés existants qui restent à être renforcés en moyens humains(spécialistes) et matériel.

Pour la prise en charge des préoccupations de l'heure, il est nécessaire de renforcer les structures spécialisées notamment celles chargées de l'insémination artificielle, de l'identification du cheptel ainsi que le contrôle permanent de performance et de production.

Cette approche doit être complétée par une amélioration et une généralisation de la couverture sanitaire à tous les niveaux.

Pour la faune sauvage, il y a lieu :

-D'intensifier la réintroduction des espèces animales rares ou disparues.

-D'actualiser la liste des espèces à protéger après l'achèvement de l'inventaire en cours.

-De créer une collection faunique nationale de référence.

-De renforcer la réglementation en matière de protection et d'assurer son application sur le terrain.

-D'organiser les associations de chasse et de les mettre à contribution dans la protection de la faune sauvage.

-De mettre en œuvre des programmes de formation orientés vers la spécialisation dans le domaine de la faune sauvage.

CONCLUSION

En conclusion, nous pouvons dire que beaucoup d'effort ont été consentis par les pouvoirs publics mais qui, malheureusement n'ont pas inversé la tendance de cette dégradation.

De plus, l'ensemble des programmes initiés ont été ainsi très technocratiques et non pas tenu compte des réalités du "terrain " qui devraient intégrer logiquement les populations qui bénéficiaient de ces programmes.

L'objectif volontariste de bien faire, ne tenant pas compte des différents intervenants dans un domaine spécifique, ajouté à l'omission des populations vivant dans ces zones à promouvoir, a donné naissance a des plans de charges certes ambitieux, mais très éparpillés avec des résultats très en deçà en rapport à l'effort déployé.

De plus les programmes entrepris, sont dans la plus part des cas, d'ordre curatif et sont mis en application sans connaissance approfondie de la situation réelle, c'est à dire, la réalisation d'un bilan exhaustif, quantifié pour que ces projets apportent des solutions bien ciblées.

Peut être, que ces projets sont ils freinés aussi par un système de planification annuel entravant la programmation dans le cadre de dossiers importants devant être traités à long terme à l'exemple de la lutte contre l'érosion ou de la préservation des ressources biologiques en général.

Au vu de ce constat, si les méthodes d'approche restent les mêmes, la tendance ira vers la persistance de cette dégradation à un rhytme qu'il est difficile d’estimer, mais certainement important.

De ce fait, le meilleur moyen de lutter contre la désertification c’est d’assurer un développement harmonieux des zones concernées et la question sécuritaire y est intimement liée.

Une situation de dégradation continu des ressources naturelles ne fera qu’engendrer la famine qui a son tour engendrera des conflits sociaux et par conséquent l’insécurité.

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SECURITY IMPACTS OF DESERTIFICATION IN EGYPT

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ABSTRACT

The Arab Republic of Egypt is situated in the northeastern corner of Africa, lying within the great Sahara desert.

Egypt has a total area of one million square kilometers and can be divided into four ecological regions. Barren deserts represent more than 90% of the country' s land area and comprise three ecological zones. The fourth region, the "Nile Valley" has a moderately developed ecological structure. Detrimental pressures on the environmental inputs are strongly reflected in the process of desertification. This, in turn, has social, economic and political consequences that affect the security.

The Eastern part of Egypt consists of four governorates, including the Southern Sinai, which occupies 18% of Egypt's total area. This governorate lacks natural resources. The local communities are comprised mainly of poor Bedouin tribes. Poverty is compelling them to move frequently for animal grazing, making additional stress on the already weak environmental structure of the region. The frequent movement of Bedouin populations is accompanied in many cases with the spread of diseases and increased rates of crime.

The Western part of Egypt occupies 36 % of Egypt's total area. It constitutes of one single governorate: "The New Valley". It significantly lacks natural resources including human resources except in oasis that are scattered throughout the region. Inland immigration to the Western Desert from the Nile Valley where the population stress is very high and poverty is widespread, represent a good "theoretical" solution to potential social and economic problems. Yet, as a result, new kinds of crimes are being introduced along the immigration pathways. This creates additional security problems in this relatively undisturbed area.

The National Action Program to combat desertification (NAP) within the UN Convention to Combat Desertification (UNCCD) takes into consideration the above mentioned factors. In order to better deal with potential security problems, it includes two development projects that aim at decreasing inland immigration and enhance Bedouin settlement.

***Desertification in the Mediterranean Region*: *a Security Issue,* 187–202.**
William G. Kepner, Jose L. Rubio, David A. Mouat & Fausto Pedrazzini, eds.

INTRODUCTION

Desertification is one of the most important challenges which threatens human life in arid and semiarid zones all over the world. It has social, economic and political consequences. Concerning its definition published by the UNCCD desertification has no direct effects on security. On the other hand, desertification has a strong relation with poverty, which in turn affects security.

The Arab Republic of Egypt has a total area of one million square kilometers. Although the river Nile is supplying Egypt with the majority of fresh water needed, ninety percent of the country's land area is still considered as a barren desert.

In order to provide baseline data for its National Action Plan (NAP), Egypt has been divided into four ecological regions (or "Agro-Ecological Zones") as follows (Figure 1).

1. North coastal areas.
2. The Nile Valley and the reclaimed desert fringes.
3. The Eastern desert and the interior of Sinai.
4. The Western desert, oases and the remote areas of the south.

Three zones out of the four have very sparse vegetation and poorly developed soils. These areas which suffer from a lack of productivity, still exhibit desertification effects, with attendantpoverty and consequences that affect the security. The fourth area, the "Nile Valley" is more moderate but still has effects of desertification including overpopulation and environmental pollution thus increasing inland immigration towards the new reclaimed areas, where overpopulation and ecological pollution are absent and new employment chances are highly available. This inland immigration, a consequence of desertification stresses, has led to additional problems for the communities. These problems include social aspects originating from mixing cultures, traditions and habits, or health aspects originating from increase communicable diseases dispersal and some are enhancing crimes, thus continuing to affect security.

Therefore, special care should be given to combat desertification problems, together with enhancing capacity building, training and awareness of the best practices to deal properly with the limited natural resources in the three-desertified regions.

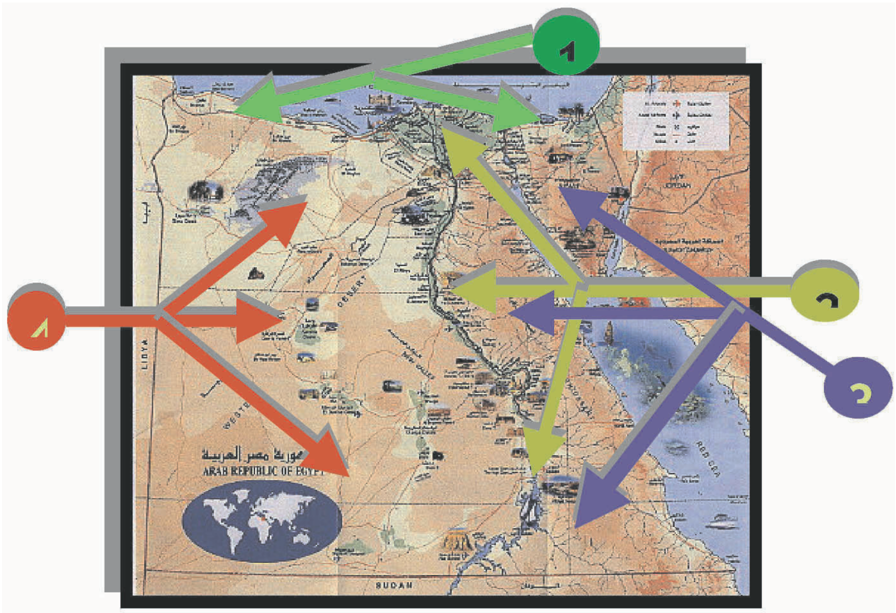


Figure 1. Egypt Four Agro-Ecological Zones

It is essential that mobilization of the national and international financial resources be directed to the threaten areas before the country becomes completely desertified. Accordingly, we strongly promote the activation of the international United Nations Convention to Combat Desertification (UNCCD) on the national and international levels.

Due to the magnitude of the problem affecting Egypt and the resultant implications on security issues, this paper will focus on just two of the ecological regions. The South Sinai and the New Valley governorates in both the third and the fourth agro-ecological zones are discussed as examples of the problem.

DESERTIFICATION ELEMENTS IN THE EASTERN DESERT AND THE INTERIOR OF SINAI

The Eastern Desert extends from the Nile Valley crossing the Red Sea to the interior of Sinai, which is considered as the Asian part of Egypt (Figure 2).

Both the eastern Desert and interior Sinai are similar in the ecological features and resources i.e., geomorphology, soil and water resources, climate and human resources. Therefore, they are considered as one region.

The desertification processes in this region are:

1. **Inappropriate practices affecting the quality of land and water resources;** out of several problems of soil and water conditions, agricultural business seems to be a very risky kind of investment.
2. **Wind and water erosion processes;** lead to removal of the fertile soil surface, hence decrease the productivity per unit area.
3. **Flash floods;** gushing floods originated from higher elevations, through dry valleys and into flood plains, cause serious damage to infrastructure, tourist facilities and large losses of fresh water and soil resources. In other words, it maximizes the losses per capita (Figure 4).
4. **Losses of plant cover and genetic resources;** this area is the only region in Egypt which receives summer rainfall. Therefore, diversified plant species are enhanced. They require proper conservation practices, overgrazing by camels and other ruminants, and deforestation for fuel resulting in serious losses of plant cover and available genetic resources. This leads to increase poverty as animal productivity decreases.

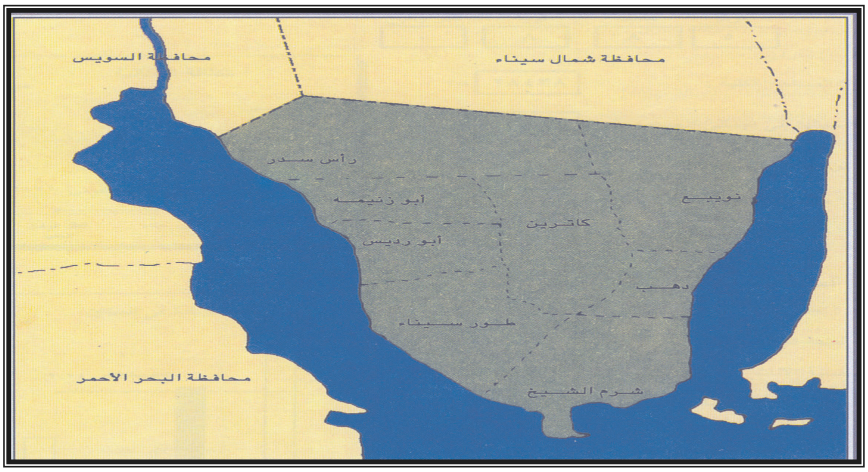


Figure 2. South Sinai Governorate

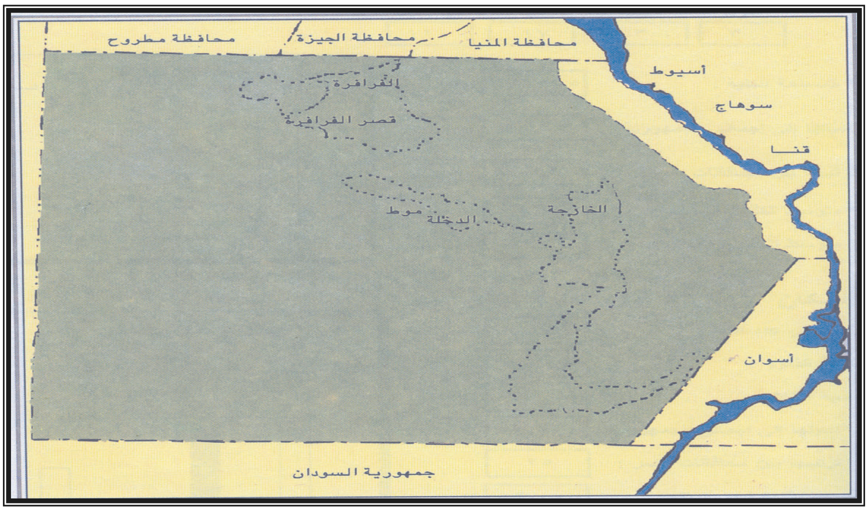


Figure 3. New Valley Governorate

Figure 4

Figure 5

Figures 4 & 5. Rocky Dams for fresh water conservation of flash floods in South Sinai

DESERTIFICATION SECURITY IMPACTS IN "SOUTHERN SINAI"

The Southern Sinai governorate occupies 18% of Egypt's total area. As indicated before, this governorate lacks abundant natural resources and has significant desertification elements that enhance poverty. The local community of the region consists of poor Bedouin tribes. They are living on growing fodder crops and vegetables and grazing animals. The community was suffering from poor infrastructure, health care, education and generally any kind of development especially through occupation. Moreover, the desertification elements that impact the region resulted in additional stress on their life. They had to wander around in the region, or immigrate towards the Nile Valley for animal grazing.

Some of them, due, in part, to poor education and high economic stress commit crimes such as growing drug plants, drugs trade, prostitution, and in some cases thieving.

The governorate started just after its independence to study the economical and social problems associated with poverty in the region. Results of field studies indicated that the desertification stresses in this region are very high and therefore poverty results. Experts advised that an urgent strategy should be introduced to improve development in this desertification-impacted governorate, taking in to consideration the socio-economic aspects of combating desertification in this region.

Moreover, studies indicated that the best investments in this region are in land reclamation, poultry, animal production, mining especially "quartz and granite" and tourism activities. A case study showed that community development can help in reducing poverty and thus crime levels in the Southern Sinai governorate in the years 1995, 1999 and 2003.

Results indicated that the investments made by both governmental (Figure 4) and private sectors in the Southern Sinai governorate enhanced the community development as indicated in (Chart 1). GDP and Human Development Index were increased as a result of increasing the total investments in the region (including combat desertification projects) in the years 1995, 1999 and 2003. As poverty levels were reduced, crime levels were also reduced. Quality of life has appeared to be enhanced. This result is clearly illustrated in (Chart 2), when population density and adult literacy were also increased. On the other hand, unfit schools have decreased, as a result of governmental investments in the education sector. This made the people in the region more reacting with the needs of the new-filed works available in the region.

Therefore, this made the community of the Southern Sinai governorate capable of receiving more inland immigrants from the Nile Valley and Delta. At the same time in the three year study even with increases in population, there were significant reductions in the unemployment rate with few health problems.

Moreover, despite of this, the governorate is considered as a tourism region, where tourism businesses and activities comprise more than 45% of the total investments, ranking the third governorate in tourism activities in Egypt. But the economy was strong enough to face international economic stresses in tourism sector in the world after 11 September 2001, to keep 0.6% reduction in the unemployment rate from the year 99-2003 comparing with a 1.6% reduction from 1995-1999 (Chart 3).

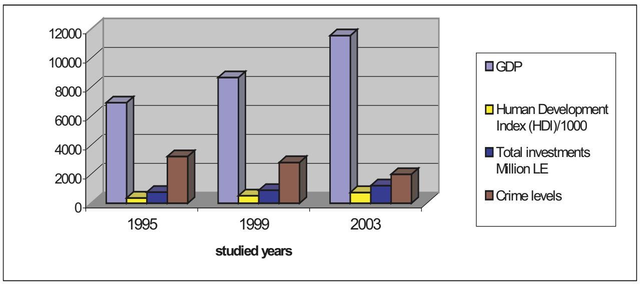


Figure 6. The relation between some socio-economic indicators and crime levels in the South Sinai governorate

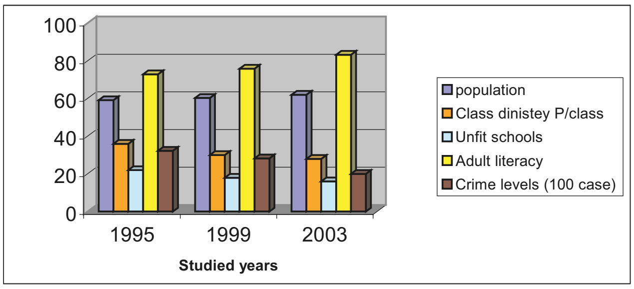


Figure 7. The decrement in crime levels as a result of the development happened in the education sector in South Sinai

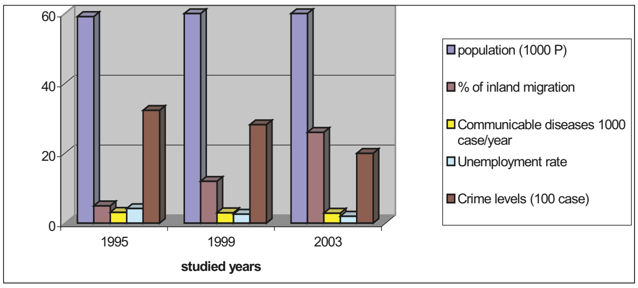


Figure 8 and 9. The relation between some socio-economic indicators and the reduction of crime levels in South Sinai

DESERTIFICATION ELEMENTS IN THE WESTERN DESERT, OASES AND SOUTHERN REMOTE AREAS

The Western Desert, which extends from the southern border towards the northwest coastal areas, is a massive plateau with a general slope towards the north, starting at an elevation of about 1000m over sea level to the extensive Qattarah depression at 134 m below sea level. The western plateau is distinguished by a uniform flat surface, 40% of which is covered with sand dunes and extensive areas of sand sheets (the Sand Sea). Several depressions of varying areas are scattered in the Western Desert including the famous Oasis of Siwa in the north, Baharia and Farafra in the central section, and Dakhla and Kharga in the south. These oases are characterized by having artesian wells of large discharge of fresh water, are mainly closed, and are characterized by fragile ecosystems, especially where populations are concentrated.

The desertification processes in this region are characterized by:

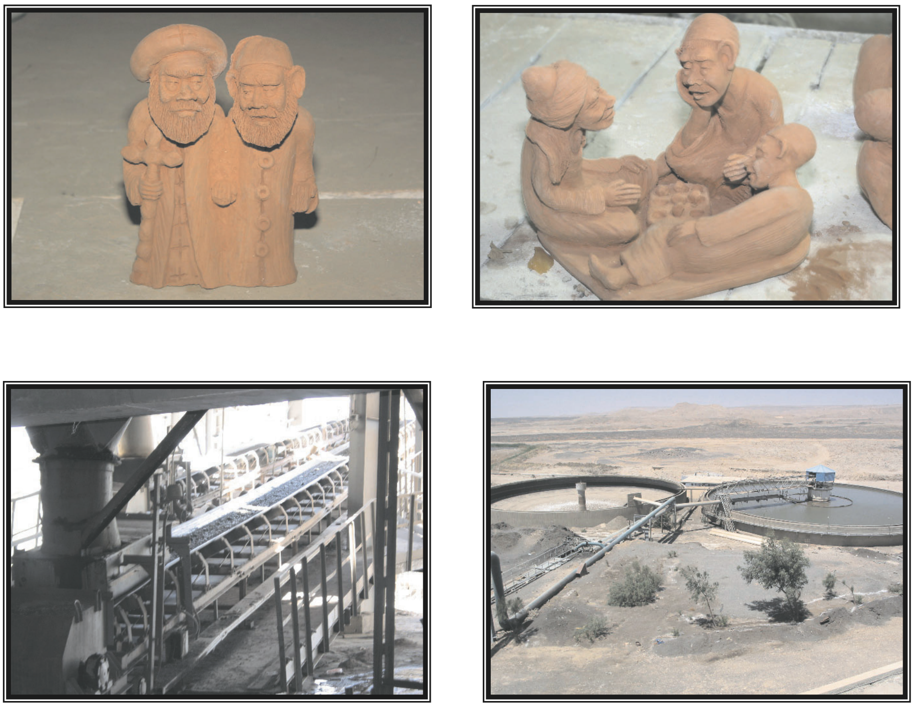
1. Over-exploitation of soils and ground water resources; leading to increased salinization and degradation of the relatively limited soil resource base. This often results in increases in the costs of agricultural development, especially on a per capita basis.

2. Sand encroachment and mobile dunes; results in a reduction in cultivated and reclaimed areas; moreover, several ventures were predicted with respect to the macro reclamation projects in the southern areas of the region which led to great losses on a per capita basis (Figure 5).

Attempts to mitigate desertification include:

1. **Management practices and sustainability;** Reasonable management practices of the environmental should be introduced to the region in order to conserve indigenous flora and fauna and the preservation of valuable genetic resources and species adapted to the harsh environment and hyper-aridity of this zone.
2. **Socio-Economic constraints;** the present population and communities of the areas affected by desertification typically are characterized by people having a low educational background. In spite of their low education, the people may have advanced craft skills (Figure 6). However, skills to address the needs of development activities are rare. There are definite needs to create incentives to reverse the present migration trends towards urban centers of the Nile Valley, in addition to the attraction of the human resources to migrate to the newly developed areas in the western desert.


Figures 10 & 11. Sand Dunes threaten infrastructure in the New Valley Governorate



Figures 12, 13, 14 & 15. Some of the investment and cultural activities available in the New Valley

DESERTIFICATION SECURITY IMPACTS IN "THE NEW VALLEY"

The western part of Egypt occupies 36% of Egypt's total area. It constitutes a single governorate: "The New Valley", which significantly lacks natural resources. The population is concentrated only in the Oases that are scattered throughout the governorate.

The local community of the region consists mainly of poor Bedouins, but out of the large investments made by the government in the early 60's, immigration pathways towards the New Valley has increased slightly over the years.

The inland immigration towards the New Valley brought to the region different cultures and habits. These new cultures and habits had to react and mix together with the original ones of the region to form the new socio-economic features of the region.

Through the inland migration pathways, new kinds of crimes were introduced to the region including prostitution, robbery, fraud, etc. As indicated before, the governmental investments in this region were started in early 60's. Taking into consideration not only the infrastructure development, but the human as well, the Egyptian government has decided that this virgin area can absorb large quantities of immigrants from the Nile Valley, providing them new employment opportunities and a more comfortable life style, removed from the overpopulation stresses in the Nile Valley.

Desertification has also had a significant impact on the economic well being of the communities. Poverty has increased in the region through a lack of development elements, such as poor infrastructure, low education levels, low health care levels and of course, very few job opportunities accompanied with very low income.

Poverty has brought to the region many problems, such as low adult literacy, high numbers of unfit schools, low educational level, in addition to many health problems. This, in turn, has encouraged illegal and inappropriate business practices and has thus increased crime levels.

Governmental field studies and reports during the years 1995, 1999 and 2003, have indicated that poverty which resulted from desertification has led to the increases of crime levels in the remote governorate.

Through the studied time As a result of increasing the total governmental investments in the New Valley (as shown in Chart 4), from

1995 through 1999 and 2003, crime levels have declined as illustrated in the GDP and Human Development Index (H.D.I.).

Similarly, crimes were reduced in the region at the same time period, out of the progress happened in the educational sector, although it was accompanied with significant increment in population (Chart 5).

Improvement in health sector and reduction in unemployment rate despite of the increase of population rate and inland immigration have also affected the crime levels (Chart 6).

From the above-mentioned case studies, results indicated that the security impacts of desertification are coming indirectly from the relationship between desertification and poverty.

When poverty occurs, a suitable media for many kinds of crimes becomes available. Some of these crimes have international importance, such as illegal drugs and weapon trades, and terrorism. Therefore, efforts on the national and international levels should be co-operated together in order to combat desertification and, hence, reducing poverty.

In Egypt, the government through its UNCCD National Action Program (NAP), has taken into consideration the previously mentioned factors, and has encouraged the local communities to share in solving these problems through development projects in the desertified regions.

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THE CHALLENGES OF LAND AND WATER RESOURCES DEGRADATION IN JORDAN: DIAGNOSIS AND SOLUTIONS

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ABSTRACT

Desertification is the loss of complexity of biological and/or economic productivity of crop-, range- or wood-lands. Reasons of such a loss is mainly due to climatic change and unsustainable human activities. The arid and semi-arid lands of Jordan are sensitive to human interference that resulted in a severe depletion of its natural resources and in different forms of land degradation due to multiple interaction of socio-economic factors. Further, degradation will continue if human activities are not carefully controlled and managed. Almost 90% of the land area of Jordan receives less than 200 mm of rainfall annually. This is reflected in poor structural stability of soils and the subsequent vulnerability to excessive erosion following shallow rainstorm events. Such a fragile ecosystem has also been manifested by non sustainable land use patterns and poor vegetative cover of the range land and the remaining forest batchs. Therefore, most of the economic activities take place on the remaining 10% of the land area and the competition between different user groups for these lands is, therefore, intense.

Factors such as livestock and grazing practices, inappropriate agricultural and irrigation techniques, the marginalizing of lands, poor socio-economic conditions and a high population growth rate as well as weak institutional arrangements need to be considered in a comprehensive and integrated framework. Rangelands are deteriorating at an accelerated rate due to widespread overgrazing, uncontrolled herd movements, firewood collection, unsuitable cultivation practices, and persisted periodic droughts, all of which worsen ecological conditions.

Cultivation of marginal lands, and unsound practices such as ploughing down slopes, and use of heavy farm machinery have accelerated rate of soil erosion and lowered land productivity. Urbanisation is also steadily encroaching onto good quality agricultural land in the higher rainfall areas of the Jordanian highlands, reducing the traditional production areas of food crops such as wheat and barley.

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Jordan suffers from a scarcity of water resources, which is compounded by poor management of existing supplies. Pumping of aquifers for irrigation and municipal uses has been exceeding their renewable safe yield. No serious attempts have been committed to improve natural recharge into these aquifers, encourage water harvesting practices or adopt water conservation measures, especially in irrigation. The current demand for municipal, industrial and agricultural water in Jordan exceeds sustainable water supply and the problem is further aggravated in dry winters like the case in the 1998/99 season.

Irrigation has made crop production possible in many areas but the long-term effects of fertilizers and pesticides on water quality, as well as on soil salinity, have been given only limited attention. Furthermore, poor wastewater treatment, and industrial pollution have compounded the problem. Current and future deterioration of water quality will have marked effects on land degradation.

Socio-economic factors contribute negatively to desertification and to efforts to combat its effects, poverty constitutes a vicious circle linking deterioration of natural resources to deterioration of livelihoods. Also, the population increase is adding an additional pressure to land and water resources, as people need to encroach further on fragile soils, sparse vegetation and limited water resources.

The institutional capabilities of the Government as well as the existing legislation and policies need to address the serious degradation of its agricultural, range and forest lands, and aim to improve land capabilities and increase production for communities will require support. Financial and technical support will be required to introduce new agricultural products, agricultural techniques, water harvesting techniques that will result in increased land productivity, yet with less pressure on fertility and water resources. Also, communities will be encouraged to engage in diversified economic activities that will alleviate pressure on natural resources. This may be accomplished through the adoption of participatory approaches that raise awareness of local communities to threats of desertification and to strengthen local institutions, which are essential for reversing desertification and environmental degradation, especially considering Jordan's transition economy.

PHYSIOGRAPHY OF JORDAN

Jordan is located between latitude 29°-33° North and longitudes 35°–39° east has a total area of about 89,200 km^2 (Figure 1). The country has a Mediterranean climate characterised by predominant winter rainfall with a dry and hot summer. Rainfall decreases gradually from north to south and sharply from west to east. The total precipitation varies greatly from year to year as well as in its distribution during the season. The rainy season extends from October till May, being heaviest between November and March. Furthermore, due to the variable topographic features of Jordan, rainfall distribution varies according to location. Rainfall averages from less then 50 mm in the eastern deserts to 600 mm in the high plateau areas of North Jordan.

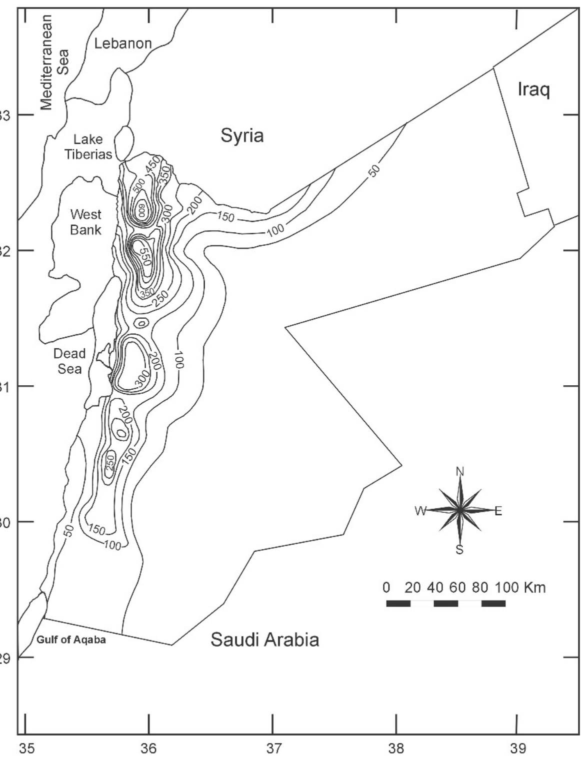

Figure 1. Map of Jordan shows the isohyetal lines of annual rainfall over the country

Jordan can be divided into four main physiographic and, subsequently, agro-climatic zones:

i. The Jordan Rift Valley (JRV) extends from Lake Tiberias in the North to the Gulf of Aqaba in the South. The area between Lake Tiberias and the Dead Sea is known as the Jordan Valley (JV). This area is considered as the major irrigated area in the country. Elevations range from 197 m below sea level (BSL) in the north to 410 m BSL at the Dead Sea shoreline. Average annual rainfall is less than 200 mm over most of the Valley with little area in the North. Soils of the Valley are associations of the orders Vertisols, Inceptisols and Entisols. It is warm in winter and dry hot in summer. This area covers 1.10% of Jordan's total area. Irrigated area is estimated at 27000 ha.

ii. The Semi Arid and Semi-Humid zones of the Highland: This highland area overlooks the JRV and comprises the mountain ridges and dissected plateau East of the Jordan valley (JV). Elevation varies from 700 to 1500 m Above Sea Level (ASL). Average annual rainfall exceeds 350 mm. Most potentially productive land occurs within this zone, especially in the north, and it covers around 0.24 million ha, 2.5% of the total area of the country.
iii. The Steppe Zone: This zone lies to the East and South of the Highland zone. The elevation descends gradually towards the East with an average altitude of 600-800 m ASL. Average annual rainfall ranges between 200 and 350 mm. This zone covers 6.3% of Jordan's total area or about 0.56 million ha. Major soil orders in this zone are Vertisols and Lithic Entisols integrating into Aridisols.
iv. The Arid Zone: This zone is known in Arabic as (*Badiah*) which includes desert plains of the granite and sand stone mountains in the Eastern, North Eastern and Southern deserts. Average annual rainfall in that area is less than 200 mm. This zone covers the remaining 90.0% of the total area, or approximately 8.11 million ha.

POPULATION OF JORDAN

Jordan’s population is characterized by high rate of births. The Statistical Year Book of Jordan (DOS, 2002) showed that in 1994 the population was 4,139,000 (census results). The figure increased to 5,182,000 in 2001. The crude birth rate for the same years were 32 and 28 per thousand, respectively. The rate of natural population increase dropped in the same period from 2.7 to 2.3%. The same period witnessed similar drop in the population growth rate from 3.3 to 2.8% but, obviously, the percentages of actual growth rate were higher than the corresponding figures of natural growth rate due to influx of Jordanian expatriates and non Jordanian cheap labourers (136,573 workers carrying valid working permits).

Due to the high population growth rate, large percentage of the citizens are concentrated in the ages less than 9 years (27.6%). Those who are less than 19 years comprise more than half the population (50.5%). Such a high percentage imposes heavy economic burden on Jordanian families as shown by the statistics of the percentage of the working age group of 15-19 year old (study ages) to be 4.9% of the total working groups of all ages.

About 2 million (1,971,750) people live in the capital Amman District which has an area of 8231 km^2 (population density of 239.6 persons per km^2). Next to Amman comes Irbid then Zarqa Governorates with the respective population of 924,470 and 815,130 people and densities of 570.3 and 199.8 persons per km^2. To the contrary, the lowest population density is that of Ma'an Governorate (3.0 persons per km^2) which has the largest area of 33,163 km^2.

The high population densities in the relatively most fertile land of Irbid Governorate had imposed serious stresses on land quality of a country characterized by aridity. Such stresses are manifested by soil erosion due to deforestation, overgrazing, and unsustainable farming practices, especially in upland areas where wheat, Jordan's main crop, is grown.

ECONOMIC DEVELOPMENT IN JORDAN

While the population growth rate of Jordan is quite high, the growth rate was compounded by the successive waves of refugees that have come into the country as a result of series of conflicts in the region. The impact of these sudden increases of population, where people have always lived in conditions of limited natural resources, has put severe stresses on the social, economical, political and environmental sectors of the country. Currently, 90% of the population live on 10% of the surface of the country, with close to 2 million people living in Amman and its environs. More recently, Jordan has maintained a wide-ranging program of economic restructuring and reform developed in co-operation with the IMF and the World Bank. Economic stability at a macro level has been restored and the debt burden is more manageable than it was five years ago. However, there are increasing concerns about economic stagnation and overall economic growth rates are not encouraging. Unemployment is a persistent and growing problem and poverty levels remain unacceptably high. Within the region, Jordan's comparative advantage continues to rest with its well-educated population, world class tourist attractions, stable Government, and clear commitment to market-oriented economic reform.

With a Human Development Index of 0.729 and an adjusted real GDP per capita of $4977.44 ranking among the group of countries with Medium Human Development Indexes (UNDP Human Development Report, 1998).

WATER RESOURCES OF JORDAN

Jordan's water resources consist primarily of surface and ground water. Renewable water resources are estimated at about 780 million cubic meters (MCM) per annum, including ground water (275 MCM/year distributed among 12 basins, Figure 2) and usable surface water (505 MCM/year distributed among 15 catchment basins, Figure 3). An additional 143 MCM/year of ground water is estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored, but at least 50 MCM/year is expected to be available for urban uses after desalination (JICA, 1995). Reclaimed wastewaters (RWW) are being used on an increasing scale for irrigation, primarily in the Jordan River Valley, and can provide at least an additional 80 MCM/year until the year 2010 (El-Naser, 1999).

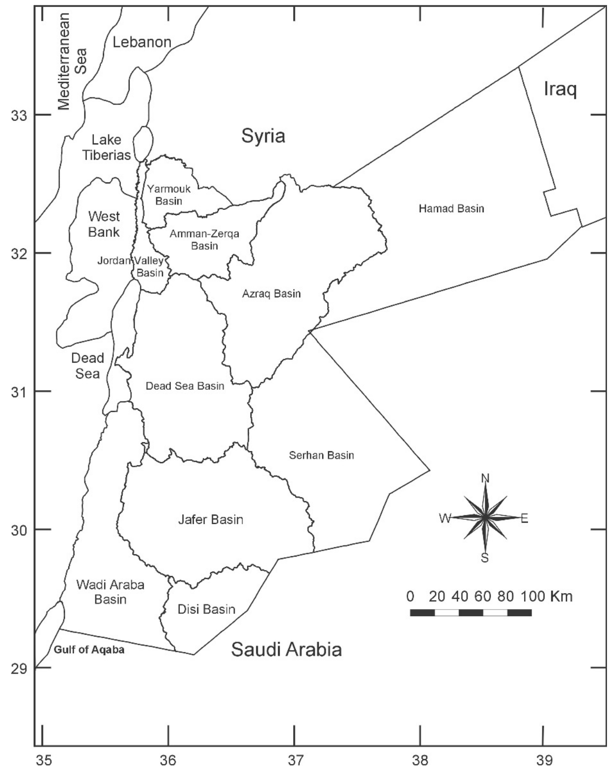

Figure 2. Watersheds of Jordan

Ground water is the major source of water supply in the country. Jordan's water budget for 2000 was approximately 817 MCM, of which more than 473 MCM was provided from ground water sources (412 MCM from renewable; 61 MCM from non-renewable) (Table 1). The total annual recharge of ground water in Jordan is approximately 275 MCM; consequently, about 138 MCM/year was overpumped from ground water resources in 2000.

Surface waters contributed approximately 38% (271 MCM) to the 2000 water budget. Approximately 72 MCM of RWW were reused in 2000 (7% of the water budget). In the last decade, treated wastewater has become an important water resource for restricted uses and has been actively incorporated into the strategic planning of water policy makers in the country.

Table 1. Sources of water and their uses in the year 2000

Water Resource	Water Use Sector (MCM)				
	Municipal	Industrial	Irrigation	Livestock	Total use
Surface water	53.309	2.537	209.670	6.000	271.516
- Jordan Rift Valley	38.464	2.537	121.180	0	162.181
- Springs	14.845	0	38.000	0	52.845
- Base and Flood	0	0	50.490	6.000	56.490
Groundwater	185.735	34.156	252.300	1.413	473.604
- Renewable	176.362	29.586	204.644	1.409	412.001
- Nonrenewable	9.373	4.570	47.656	0.004	61.603
Reclaimed Wastewater	0	0	72.033	0	72.033
- Registered	0	0	66.933	0	66.933
- Not Registered	0	0	5.100	0	5.100
Total	239.004	36.693	534.003	7.413	817.153

Source: Ministry of Water and Irrigation. Personal Communication. 2002.

GROUND WATER QUALITY

Groundwater quality can be affected by both natural and anthropogenic activities. In aquifers unaffected by human activity, the quality of groundwater results from geochemical reactions between the water and rock matrix as the water moves along flow paths from areas of recharge to areas of discharge. In general, the longer groundwater remains in contact with soluble materials, the greater the concentrations of dissolved materials in the water. The quality of groundwater also can change as the result of the mixing of waters from different aquifers. In aquifers affected by human activity, the quality of water can be directly affected by the infiltration of anthropogenic chemicals or indirectly affected by alteration of flow paths or geochemical conditions.

Contamination of fresh groundwater by saline water is a common problem in the region. In humid areas of abundant recharge, potential groundwater salinization is limited because of the natural flushing of salts by freshwater. Conversely, in semiarid areas, the absence of natural flushing by freshwater enhances the accumulation of salts and saline water.

In addition to natural sources, groundwater quality can be affected by agricultural, municipal, and industrial activities in the recharge zone of the aquifer. Potential sources of contamination include recycled irrigation water, wastewater from human activities, and waste by-products from industrial activities. Nitrate is an important constituent in fertilizers and is present in relatively high concentrations in human and animal wastes. In general, nitrate concentrations in excess of a few milligrams per liter indicate that water is arriving at the well from shallow aquifers that are polluted from human or animal waste, or from excess nitrates used in agriculture.

A more common problem in Jordan is that agricultural practices have had to contend with irrigation waters of increasing salinity in recent years. In some areas, the increase in salinity has resulted due to over-abstraction of ground waters, sometimes with a resultant intrusion of more saline ground waters, especially in Dhuleil and Azraq areas. In other areas, increased usage of RWW or mixing of fresh waters with saline spring waters, particularly in the southern part of the JV, has adversely affected sustainable agriculture. In addition, several major springs have been contaminated by fecal coliforms (e.g., Wadi El Sir, Ruseifa, Qairawan, Deek, Teis, Qantara, and the springs near Salt). These springs alone produce more than 15 MCM/year to the domestic water supply. Numerous ground water production wells, some associated with these springs and others along the Zarqa River, have become seriously contaminated with fecal coliforms.

WATER RESOURCES DEVELOPMENT PROJECTS

In 1957, the Government of Jordan started to implement irrigation projects in the JV in order to provide the area with sufficient quantity of irrigation water. The work started by implementing King Abdullah Canal (KAC) project which has a total length of 110 km. It is a transport open canal, with a maximum width of 11.30 m, a maximum (water) depth of 2.80

m and a maximum conveyance capacity of approx. 20 m^3/s. The canal irrigates approximately 23,710 ha of arable land.

The water resources for the canal come from the Yarmouk River (48%), the conveyer from Lake Tiberias (24%), King Talal Reservoir (KTR) (15%), Mukheibeh wells (5%), the side wadis in the northern part of the Valley (4%) and the side wadis in the southern part of the Valley (4%). Apart from the area irrigated from the Canal, approximately 745 ha is irrigated directly from other sources (from KTR, and Hisban-Kafrin Dam), through separate conveyors (MWI, 2000).

Several dams were constructed during the last three decades; their overall holding capacity is 160 MCM, with a total investment cost of \$365 million. Major properties of these dams are presented in Table 2.

Table 2. General characteristics of major reservoirs of Jordan

Reservoir	Location	Live Storage (MCM)	Height (m)	Cost (Millions Dollars)
King Talal	Zarqa River	**75**	108	102.1
Wadi Arab	Wadi Arab	16.9	82.5	60.1
Karamah	Wadi Malaha	55	45	76.3
Kafrein	Wadi Kafrein	8.5	37	27.0
Wadi Shueib	Wadi Shueib	1.43	32	1.7
Sharhabeel	Wadi Zeglab	3.9	48	11.7
Total		160	---	364.6

The potential for further development of surface water resources rests principally with the construction of the proposed Al-Wehda Dam on the Yarmouk River. This dam would provide an annual safe yield of about 105 MCM, 55 MCM would be needed for manufacturing and industrial uses in Irbid region and the remaining 50 MCM will be used to intensify agricultural production in the JV.

In the JV, there are about 240 tube wells in South Jordan Valley distributed in three major areas, out of which, 104 tube wells In Kufrein area, 62 tube wells in South Shuenh area and 58 tube wells in Rama area. The remaining number is distributed in different areas in Southern JV. Only 64% of these wells are licensed, and total annual extraction was about 35.4 MCM in 1999, about 28.2 MCM of which were used for agriculture activities, 1.3 MCM were used for industrial purposes and the remaining were used for dual purposes. Average water salinity in these wells is 1600 ppm, which is considered of high value for some types of fruit trees. Mostly, water extracted from these tube wells has a value of salinity about 2000 ppm, which restricts the expansion of some type of agriculture cultivation using this quality of water.

Although irrigated agriculture in the JV comprises the food basket of the country, irrigated agriculture in the highlands has become of comparable significance. Sections to follow will be devoted to describe all environmental components that may contribute to land degradation or combating desertification in both the Highland and the most important strategic area of the JV.

AGRICULTURAL DEVELOPMENT IN JORDAN

Agricultural sector in Jordan consumes about 65% of the total available water supply, where municipal, industrial and rural sectors consumption was 28.9%, 4.7% and 1.4% respectively, in 1999 (Ministry of Water and Irrigation (MWI), 2000). Although the agriculture sector consumes more than 65% of the country's water resources, contribution of agriculture to the gross national production was less than 2.25% in the year 2001 (DOS, 2001). In order to maintain an effective balance in water supply and demand importation of food grains and energy must be increased. The current virtual water imported, according to estimates of MWI, is about 6.0 billion cubic meters per year. This is approximately seven times Jordan's annual water budget and 10 times Jordan's renewable water supply (El-Naser, 1999).

Total irrigated area in Jordan is estimated to be about 76.5 thousand ha in the year 2000 distributed as follows: JV and Southern Ghor 28.2 thousands ha which forms 38% and high lands 47.6 thousand ha which forms about 62 % (DOS, 2002).

IRRIGATED AGRICULTURE IN THE HIGHLAND

Jordan is one of the most water scarce countries in the world. Consequently, water is the single most critical natural resource since virtually all aspects of sustainable economic, social, and political development in the country depend on the availability of an adequate water supply.

With an irrigated area of about 843,000 dunums distributed between the JRV (316,000 dunums) and the highlands and desert areas (527,000 dunums), agriculture is the biggest water consumer (~ 65% of the available water). Expansion in irrigated agriculture in the Highland and deseret areas has been very rapid in the past three decades of the last century. For example, irrigated area in the 1976 was only 69,088 dunums. Irrigated areas in the highland and the Desret utilize more than 50% of the groundwater resources which, in turn, amount to 54% of the water resources of Jordan. Twelve groundwater basins have been identified in Jordan; these include two fossil aquifers: Al-Disi and Al-Jafar. Some of these basins have more than one aquifer. The annual safe yield of the renewable groundwater supply is estimated to be 277MCM. An additional 143 MCM per year are considered available from non-renewable fossil aquifers that are sustainable for between 40 and 100 years. In 1998, over-draft was about 157MCM in six basins. Consequently, the water level in these basins is declining and some aquifers (especially Al-Dhuleil Aquifer) show serious deterioration in their water quality (increasing chloridic salinity, Abu-Sharar and Rimawi, 1993) due to increased salinity.

Water demand in Jordan is being met by over pumping from renewable aquifers, exploiting fossil water, and curbing use by rationing of the municipal water supply. The water scarcity is exacerbated by rapid population increases, the growing industrial and services (including tourism) sector, inefficient irrigation practices, inadequate wastewater treatment capacity, and inefficient water management and use. A national strategy focusing primarily on new water supply is neither technically, nor financially feasible. Consumption and demand management are key to Jordan's economic and social future. Over the short term, the best and most cost-effective options for reducing the gap between demand and supply are improving the management of existing water resources and improving the quality and availability of TWW for reuse in irrigation. Although reduction in water consumption should be carried out on the expense of irrigated areas in the Highland, recent studies demonstrate clearly that agricultural demand for water can be reduced without decreasing the total irrigated area or the value of agricultural production (*Ad hoc* Committee of Irrigated Agriculture, 2001). Indeed, proper water usage along with proper production technology and crop selection might actually increase agriculture's contribution to the economy and at the same time decrease its water usage. Switching cropping patterns to encourage the import of "virtual water" would further benefit the issue of water conservation and curtail highland losses to salinity.

In general, farmers in Jordan can be classified into four categories: 1) educated farmers, including some professional agricultural engineers, 2) tribal community farmers 3) illiterate farmers, and 4) Investors on large farms that usually employ professional agricultural engineers to run the farms. Irrigated farming in the Highland has been developed by almost all of the above categories. Because of specific skills required in agricultural production in the Highland, irrigated agriculture in that area has become a major source of soil salinization and erosion. Farmers usually tend to abandon their land once salinity buildup reaches a threatening level. Moreover, net return from unit volume of irrigation water is usually far below the corresponding values recognized from irrigated agriculture in the JV (Abu-Sharar and Battikhi, 2002).

Cropping patterns in the highlands range from vegetables and fruit trees, to wheat and barley. The predominant vegetables are tomatoes, potatoes, onions, watermelon, cauliflower and squash while the predominant trees are olives, grapes and citrus. In 1998, the total water consumption for irrigation in the highlands was 453 MCM of which 242 MCM were extracted from groundwater and the remaining 211 MCM from surface water resources. Accordingly, irrigated agriculture in the highlands uses about 55% of Jordan's groundwater, but returns very low value for cubic meter. Most vegetable crop are cultivated in open fields and, subsequently, their water consumption is relatively high provided the relatively long growing season that is characterized with high temperatures and long days.

In 2000, the Policy Implementation Project funded by USAID carried out a Rapid Appraisal study on the Amman-Zarqa Basin farmers to measure, among other things, on-farm water efficiency. The study concluded that the highlands farmers could significantly improve irrigation water efficiency through obtaining a better understanding of the inefficiencies of their current systems and through adopting improved irrigation practices. The estimated potential water saving was in the range of 15-20%.

CAUSES OF DESERTIFICATION

Desertification in Jordan is due to a combination of changing natural conditions over a long (geological) period and the effects of man on the land within the historical period. Agricultural and pastoral activities have been the dominant human factors in desertification since the Roman Era. Natural causes of desertification can mainly be attributed to:

1. Soil erosion in the Highland Zone: Long term records of the Highland weather stations repeatedly show rainstorm events of more than 100 mm depth of, most likely, high rainfall intensity.

Such intense rainstorms usually generate extensive soil erosion, especially at steep and long slopes. Moreover, man induced destruction of natural forests by deforestation and expansion of farmland (land cultivation) and grazing into these forests over the past centuries.

2. Overgrazing of the rangeland in the Steppe Zone by sheep and goats. Overgrazing is beyond the capacity of that and, thus, a steady degradation in the land quality has been taking place. Very poor results and often crop failure generally accompany the expansion of arable farming onto these lands. Structural stability of the surface soil, and thus extent of soil erosion occupies intermediate grade between these of the Highland and the Desert soils.
3. Wind and water erosion in the Desert region. Such a process is of a history-long age. Desert soil has a phenomenal poor surface structural stability which can be manifested in terms of surface crust formation and, subsequently, very low steady state infiltration rate which usually does not exceed 5.0 mm hr^{-1} (Abu-Sharar 1993; 1996; Abu-Sharar and Salameh, 1995). The fragile soil structure is subject to extensive wind and water erosion, especially when rainfall intensity exceeds infiltration rate. In addition, dramatic changes brought about by irrigated agriculture and, the subsequent, desertification trends on the improved lands remain of concern.

As for the JRV, Qaisi (2001) reported additional environmental problems like declining water quality, depletion and pollution of groundwater resources, destruction of natural vegetation and habitats, loss of stratification and hydrological stability in the Dead Sea, increasing collapse phenomenon in the Southern Ghors and deterioration in landscape visual amenity.

EFFORTS TO COMBAT DESERTIFICATION

Field observations indicate a gradual increase in land degredation in Jordan. Major reasons for such a phenomenon are argued to be encroaching urbanization into the traditional agricultural land, persistent drought seasons, water shortage, deforestation, losses in land productivity, decreasing agricultural feasibilty of traditional crops, decreasing availability of cheap labor, abolishing agriculture to other professioons, discouraging environment of investment in the agricultural sector, increasing prices of agricultural inputs, deficiencies in "know-how" of soil-water management in the arids and the introduction of new competitive commercial crops in irrigated agriculture (Abu-Shriha, 2003).

Consequences of land degradation are thought to comprise diminishing agriculture areas, deserting agriculture to other professions, switch to cash-crops like tobbacco, over exploitation of natural land, practicing monoculture crops (losses of native genetic resources), over exploitation of natural vegetation cover for human and animal use, soil and water pollution by chemical fertilizers and pesticides.

CONVENTIONAL METHODS OF SOIL CONSERVATION

The following practices are employed in soil conservation projects in Jordan (Abu-Sharar, 2001):

1. Contour cultivation.
2. Ripping.
3. Terracing: Here different types of terraces may be constructed depending on soil type and climatic conditions. These terraces are employed in high and low rainfall areas and can be classified as follow:
   - 3.1. Diversion banks.
   - 3.2. Contour (absorption banks).
   - 3.3. Gradoni terraces.
   - 3.4. Bench terraces.
   - 3.5. Contour stone terraces.

WATER HARVESTING

More than 90% of Jordan's area receive less than 200 mm of annual rainfall. In addition, we demonstrated in earlier sections the poor structural stability of such soils which results in surface crust formation and substantial reduction in infiltration rate to a minimal value of about 4 mm hr^{-1}. In such conditions, extensive soil erosion may take place in response to shallow rainstorm of relatively low intensity. Soils of that agroclimatic zone may be rehabilitated and may become productive if:

-water for irrigation is provided in a carefully scheduled management,
-proper crop is selected, and
-soil physical conditions are improved, especially increasing soil structural stability and, subsequently, infiltration rate and water holding capacity.

The above objective can be met in a way or another by adopting techniques like spreading and detention of flood water for a finite duration to permit sufficient infiltration. In order to implement this approach, a system of structures is required. These may be classified into detention, dispersion, and diversion structures:

Detention structures

These are built of locally available material like soil, gravel, stone, boulder, and rock. Height of these structures is usually less than 10 m across wadis or valleys. The purpose is to slow down and retain flood water as well as to heal gullies. The detention structures are suitable for water detention in relatively deep wadi courses with gullied side valleys of gentle slopes. Therefore, such structures are site specific and require considerable amount of stones and provision of hauling construction material.

Dispersion Structures

Dispersion or spreading of flood water over larger areas of the flood plain is usually achieved by the provision of low-level structures (2-4 m high). These structures (known sometimes as deflection dams) are preferably constructed of gabions extending across a portion of the entire width of the alluvial plane. The flood flows are thus raised up to the top of the dam and caused to disperse over greater portion of the flood plain. The result is an increased amount of water flowing into the alluvium outside banks of the normal channel. Structures have to be designed to withstand overtopping.

Diversion Structure

The objective here is diversion of partial flood flows through a channel other than the main course of the wadi in order to benefit additional areas from the detention or dispersion of flood water. This kind of structures can be observed in the very ancient human settlement of Jawa (in the north of Jordan). Concrete or gabions are recommended construction material for that kind of structures.

JORDAN STRATEGY TO COMBAT DESERTIFICATION

Jordan has long prioritised its most pressing problems as being the scarce water resources and land degradation. Accordingly, all relevant institutions address these issues, especially the Ministry of Water and Irrigation. Jordan is one of the 30 original supporters of the World Conservation Strategy. In October 1996, Jordan ratified the Convention to Combat Desertification. National Strategy for Agricultural Development (*Ad hoc* Committee of the Irrigated Agriculture, 2001) for the decade 2000-2010 stressed on sustainable agriculture and protection of natural and biological resources. Finally, with the advent of the 21st Century, Jordan prepared its National Agenda 21. The document outlines several key areas related directly to natural resources and dryland issues and promotes the participatory approach at all levels to ensure success and sustainability. The Agenda also reflects the integrated approach to environment and development and converges with objectives of poverty alleviation and sustainable human development.

EXISTING ENVIRONMENTAL LEGISLATION

The primary environmental legislation is Law No. 12 of 1995 which has recently been substituted by the temporary Law No. 1 of 2003. Environmental legislation forms the backbone of environment protection in Jordan. The enforcement of these laws constitutes one of the most essential tools that translate theory into reality. This section highlights salient features of Jordan’s environmental management capacity, in particular these factors affecting the potential to combat desertification. Environmental legislation of relevance to combat desertification along with governmental departments to be held responsible on enacting them are categorized as follows:

Wastewater and Sewage

Water Authority Law No. 18 of 1988.Water Authority.
Law of Organization of Cities, Villages and Buildings No. 70 of 1966. Local Committee.
Public Health Law No. 21 of 1971. Ministry of Health.
Prevention of Repulsive and Fees for Solid Waste Collection within Municipality's Boundaries No. 1 of 1978. Municipalities.
Sewage By-low No. 66 of 1994.Water Authority.
Industrial and Commercial Waste Water Disposal into the Public Sewage No. 1 of 1998.
Water Authority.
Jordanian Specification No. 202/ Water: Industrial Waste Water of 2003. Water Authority.
Jordanian Specification No. 893/Water: Treated Domestic Waste Water of 2003. Water Authority.
Environmental Law No. 1 of 2003. MoW.
Agriculture Law No. 44 of 2002. Ministry of Agriculture.

Soil and Agricultural Land

Environmental Law No. 1. 2003. MoE.
Management of Natural Resources Law No. 12. 1968. Natural Resources Authority.
Agriculture Law No. 44. 2002. Ministry of Agriculture.
Management and Administration of Government Properties Law No. 17. 1974. Finance Ministry.
Jordan Valley Authority Law No. 19. 1988. Jordan Valley Authority.
Law of Organization of Cities, Villages and Buildings No. 79. 1966. Prime Minister.
Jordanian Specification JS 1145/ Sludge. 1996. Water Authority.
Civil Defense Order No. 1: The Protection of Forestry in Jordan.1993. Civil Defence.

Biodiversity

Environmental Law No. 1. 2003. MoE.
Agriculture Law No. 44. 2002. Ministry of Agriculture.
Law of Organization of Cities, Villages and Buildings No. 79. 1966. Ministry of Agriculture and Local Committee.
Protection of Birds and Wild Life By-law No. 113. 1973. Royal society for the Conservation of Nature.
Decision No. 1/ 5 for Cattle farms. 1990. Ministry of Agriculture.
Decision No. 2/ 5 for Sheep farms. 1990. Ministry of Agriculture.
Decision No. 3/ 5 for Rabbit farms.1990. Ministry of Agriculture.
Decision No. 4/ 5 for Fish Farms. 1990. Ministry of Agriculture.
Decision No. 4/ 5 for Poultry Farms. 1990. Ministry of Agriculture.
Decision No. 1/ T for Registration of Animal Feed Centers. 1996. Ministry of Agriculture.
Civil Defense Order (Decision) No. 1 for the Protection of Forestry. 1993. Civil Defence.

Desertification

Environmental Law No. 1. 2003. MoE.
Agriculture Law No. 44. 2002. Ministry of Agriculture.

Human Settlement

Public Housing and Urban Development Law No. 28. 1992. Public Housing and Urban Development Corporation.
Management and Administration of Government Properties Law No. 17. 1974. Finance Ministry.

Land Use Planning

Law of Organization of Cities, Villages and Buildings No. 79. 1966. Prime Minister.
Public Housing and Urban Development Law No. 28. 1992.
Public Housing and Urban Development Corporation.
Jordan Valley Law No. 19. 1988. Jordan Valley Authority.

Building, Cities and Villages Organization By-law No. 19. 1985. Greater Amman Municipality.
Building and Organization of the City Amman No. 67. 1979. Greater Amman Municipality.

Cultural and Archaeological Sites

Law of Antiquities No. 21. 1988. Archaeological Department.
Law of Organization of Cities, Villages and Buildings No. 79. 1966. Prime Minister.
Management of Natural Resources Law No. 12. 1968. Natural Resources Authority.
Quarries By-law No. 8. 1971. Natural Resources Authority.

Solid Waste

Environment Law No. 1. 2003. MoE.
Public Health Law No. 21. 1971. Ministry of Health.
Law of Organization of Cities,, Villages and Buildings No. 79. 1966. Local Committee.
Prevention of Repulsive and Fees for Solid Waste Collection within Municipality's Boundaries No. 1. 1978. Municipalities.
Jordan Specification No. 431/Storage–General Precautionary Requirements for Storage of Hazardous Materials. 1985.

DEFICIENCIES IN LEGISLATION

Deficiencies in Jordan legislations can be summarized as follow:

1- Interdepartmental and multiple responsibilities on the environment sector. In the lack of coordination, this leads to hinder enacting laws, bylaws and instructions.
2- Slow court proceedings.
3- Personal and social interferences with legal procedures in favour of law violation.
4- Ambiguities in some law articles that help avoid penalties.
5- Absence of scientific reference to each case of argued environment

component which help avoid conviction.

6- Absence of comprehensive legislation concerning land use.

7- Some of the old penalties have become light in comparison with the magnitude of the environmental damage it deals with.

8- The current Environment Law No. 1 of 2003 has several deficiencies of which:
-absence of any article dealing with soil conservation and combating desertification.
-absence of articles dealing with crimes of environmental nature like illegal dumping of dangerous solid wastes or their importation to the country, contaminating soil, civil responsibilities and compensations for environmental damages.
-absence of public participation in environmental policy making and the public role in environmental legislation.

RECOMMENDATIONS TO REHABILITATE JORDAN LEGISLATION

1- Occasional review and updating of the environmental legislations.
2- Passing a bylaw dealing with soil conservation and combating desertification.
3- Establishment of environmental fund to help combat desertification and to be sponsored *in-part* from the fees and fines generated from the application of the Environment Law No.1 of 2003.
4- Encouraging the industrial sector to preserve and promote environment by passing a legislation that ensures partial tax and fee exemptions when complying with the requirement of healthy environmental.
5- Establishment of a specialized Environment Court.

In addition to the above recommendations, several local experts recommended the following:

1-Acknowledgement of the necessity to amend the current legislation to ensure that Jordan can fulfill its obligations under in the international Convention to Combat Desertification;
2-Enforcement of Article 25 of the Environment Law No.1 of 2003.
3-Authorization of the Jordan Society to Combat Desertification to undertake responsibility in combating desertification.
4-Drafting and Issuing a by-law to Combat Desertification.
5-Encouragement and training of Jordanian women to start income-generating projects such as agribusiness. This can be achieved through the integration strategies for poverty eradication into efforts to combat desertification and to mitigate adverse impacts of drought.
6-Strengthening local, regional and international cooperation.
7-Cooperation among interested governmental organizations.
8-Establishment of proper institutional mechanisms to avoid duplication and to promote mobilization and usage of existing bilateral and multilateral financial mechanisms and supports in this regard.

COOPERATION WITH INTERNATIONAL AGENCIES

In addition to the UNCCD, Jordan is party to other environmental-related international agreements including Bio-Diversity, Climate Change, Ramsar Convention, International Trade and Endangered Species, and Ozone Layer Protection. Jordan has developed a National Environmental Action Plan in which environmental issues were prioritised and various solutions put forward. The Government is attempting to address the serious degradation of its agricultural, range and forestlands, aiming to improve land capabilities and increase production for communities. Ministry of Environment has launched the process for the development of a strategy and action plan for the sustainable use of biodiversity.

Given the limited resources, at both human and financial levels, various agencies play an important role, through financial and technical assistance to help Jordan meet these objectives. Most of these initiatives address aspects of land degradation and contribute to the national efforts to combating desertification. However, a lot is still need to be done mainly in areas of co-ordination, harmonisation and integration, as well as capacity building and the provision of additional resources.

UNDP is among the key players in the environment field and has been and continues to be involved in development projects and programmes in Jordan. UNDP has been involved in a number of projects, with the Government of Jordan, which has a bearing on dry land management. UNDP assisted the Ministry of Water and Irrigation in a project to help in planning and managing Jordan's water resources. *The project involved upgrading a databank containing information on Jordan's water resources and consumption as well as transfer of technology to measure water supply versus usage.*

UNDP has also been involved in a number of projects that addresses biodiversity issues. Jordan has completed its Biodiversity Country Study and is now proceeding with the preparation of the Biodiversity Strategy and Action Plan, an obligation to the Convention on Biodiversity. Another initiative that has a bearing on dry-land management is the regional project on conservation of agro-biodiversity, which focuses on identifying, and conservation of the major threatened crops. The project has five national components in countries of the region that are implemented in a complementary manner.

Another area of focus is supporting the Government of Jordan to its efforts in the Climate Change area and contribution towards the decrease of GHG emissions and global warming. UNDP assisted the Government to prepare and submit its communication report and to further assess the country in studying the vulnerability of the water sector to climate change effects. This additional component focused in testing different scenarios of climate change and the preparation of mitigation scenarios.

UNDP has also been involved in the provision of technical and financial assistance in the field of natural reserves protection and management, two main globally significant reserves were addressed, mainly the Dana Wildland and Azraq wetland Reserves. The efforts focused protection and management aspects through promoting the participation of the local communities in these efforts. *The participatory approach endeavour resulted in addressing the socio-economic factors of these communities and contributed to the creation of employment opportunities, mainly in eco-tourism activities, improvement of the standard of living*, and thus ensuring the sustainability of the projects and replication of the experiences in the region.

Another major endeavour of UNDP, that also has a bearing on dry land management, is the Debt Swap initiative that is being promoted as an option to debt forgiveness by the main debtor of Jordan provided that debt is paid through the implementation of projects that address environmental problems. In a participatory approach, UNDP assisted different players in the environment field, both governmental and non-governmental, in the preparation of a priority list of projects that are in line and compatible to the priority list of the debtors. The list has a wide range of projects that focuses on dry land management and combat desertification issues, and will be promoted to different donors and international agencies. *The initiative,* awaiting government endorsement, *can be utilized as a main tool for resource mobilization and can be used in the preparation of the project's resource mobilization strategy*.

The UNDP/GEF Small Grants Programme has supported small NGOs and local communities in their initiatives in tackling a range of environmental problems at the grass roots level. Many of these initiatives addressed issues relevant to halting land degradation and water management. The programme provides a successful example for *involving local communities, mainly women, to ensure the continuity and sustainability of efforts that directly affect the livelihood of these communities.*

The World Bank (WB) has been involved in several projects in Jordan largely dealing with economic restructuring. Currently, the WB, in collaboration with the Ministry of Agriculture, is implementing an "Initiative for Collaboration to Control Natural Resources Degradation (*Desertification of arid lands in the Middle East*)".

The German Technical Co-operation (GTZ) is supporting numerous projects in Jordan focussing on water, agriculture and institutional strengthening. GTZ assists the formation of national information systems for the Ministries of Planning, Economics, and Finance as well as a series of downstream institutions in order to improve state services such as procedures for customs, land registry, and up-to-date standardisation, metrology and norms.

Another major player is the USAID programme that addresses three concerns central to Jordan's future development: too little water; too many people; and too few jobs. This formulation highlights the fact that the real constraints in Jordan are systemic in nature, cutting across several sectors at once. USAID's Jordan strategy for the current five-year period (1997-2001) incorporates three strategic objectives *linking environmental issues to socio-economic factors:*

1- Improved water resources management: to increase the efficiency of water use in Jordan through innovative technologies and to improve the quality of wastewater used in agriculture.

2- Increased practice of family planning: to improve the quality and availability of health care for mothers and infants and to meet the demand for family planning services in Jordan.

3- Increased economic opportunities for Jordanians: To provide balance of payments support to help reduce Jordan's external debt burden; to assist Jordan in implementing its economic reform program and to increase the availability of credit to micro-enterprises and small businesses.

CIDA is supporting "The Sustainable Rangeland Management Project" which is hosted by the Ministry of Agriculture and aims at developing and maintaining a programme to prevent soil erosion and to propose a rangeland management scheme to prevent further degradation. Its expects to institute a rangeland directorate, develop an information network to facilitate exchanges on local experiences in rangeland management and to strengthen relationships between the various organisations with work concerning rangelands. In addition it tries to *contribute to the alleviation of poverty in disadvantaged rural communities through income generating activities as well as trying to bring them into the process of rangeland management.*

EuroCom initiated a new project in May 1999 which is being co-financed by the EU budget line "LIFE Third Countries". The project focuses on the "Environmental Law Enforcement". The co-operation partner of EuroCom is the General Corporation for Environment Protection. The current project should take into consideration ongoing activities in order to avoid overlap and to maximise resources used and to play a co-ordination role for a coherent framework.

NONGOVERNMENTAL ORGANIZATIONS

Non Governmental Organizations (NGOs) activities in Jordan address two main issues: the problems facing the Palestinian refugees living in the camps and the people who live under the poverty line. These activities consist mainly in solving the specific refugees' problems in urban or suburban areas, whereas the help for the poor is mainly provided in the areas far from the city centres, especially in the desert areas.

In the past decade, however, a variety of environmentally oriented NGOs have sprung up, alongside the increased activities among some of the more established ones such as the Royal Society for the Conservation of

Nature (RSCN). RSCN mainly manages protected areas; however, its main impact lies in *the promotion of local community involvement, awareness raising, and focus on socio-economic factors.*

The Jordanian Society for Desertification Control & Badia Development (JSDCBD) has specialised in studies and research related to desertification and Badia development. It tries to identify desertification problems, causes and impacts and attempts to propose solutions. In co-operation with other NGOs such as the Jordan Environment Society (JES), it has *focused on utilizing media channels to raise public awareness to combat desertification* and seeks their support for its programme. It emphasises the protection of natural plant cover to establish environmental balance and promotes the investment in water harvesting projects.

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DRYLAND DEVELOPMENT, DESERTIFICATION AND SECURITY IN THE MEDITERRANEAN

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ABSTRACT

Bioclimatically, The Mediterranean basin comprises a transition between southern desert (Saharian-Arabian deserts) and northern non-desert (European woodlands). Using UNEP´s aridity classification, the political boundaries of all Mediterranean countries include the whole range of dryland types: from south to north, southern Mediterranean countries which are closer to the Sahara-Arabian deserts than the northern Mediterranean countries, have hyper-arid drylands (true deserts), semi-arid drylands, and dry-subhumid drylands; north Mediterranean countries have semi-arid drylands, dry subhumids drylands, and non-drylands regions – humid areas. The UNCCD does not regard hyper-arid drylands as prone to desertification, hence all Mediterranean countries have within their boundaries areas prone to desertification and areas not prone to desertification; in southern Mediterranean countries not prone to desertification are the southern-most and driest regions, and in the northern Mediterranean countries – these are the northern-most and driest region, and in the northern Mediterranean countries – these are the northern-most and least dry regions. The eastern Mediterranean countries – Israel, Lebanon and Syria combined, present the full south-northen gradients of the global drylands. The southernmost of the three, Israel comprises all four dryland types within its boundaries with more than half of its territory prone to desertification, and the analysis of its development, desertification and security can serve as a case study with lessons to the Mediterranean region as a whole.

From the dawn history the country has been under intensive land use by humans, including pastoralism and cropping. The new Israel viewed its semi-arid areas, most prone to desertification, as a security risk, and set out to settle them mainly through agricultural development, extensive afforestation projects, rehabilitation of vegetation and restoration of water-related ecosystem services. Exploitation and grazing pressure on the dry subhumid scrublands have been reduced, with fast transition of the vegetation to woodland formation, with restoration of water and soil related ecosystem services.

The sustainability if this agricultural development and its potential to avert salinization were driven by transportation of high-quality irrigation water from dry subhumid-generated resources to drier regions. This has been augmented by water

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conservation hinged on drip irrigation, and by research and extension services. Dry subhumid areas, arid and hyperarid areas have benefited from the agricultural experience gained in the semi-arid region and the infrastructure established to supor tit. Afforestation practices developed for the dry subhumid areas have "migrated" to semi-arid and arid regions. The discovery of geothermal, brackish fossil groundwater and the adaptation of greenhouses to growth houses in dry and hot regions provided farmers with options of intensive cash-crop agriculture and aquaculture – practices that are economic on land use and hence of little if any desertification impact.

During its first decades, Israel rehabilitated many previously desertified areas and prevented further desertification. But in recent decades desertification has reemerged. In the dry subhumid areas there is soil salinization, and increasing impenetrability of dry sughumid woodland and "bush encroachment" leading to degraded range quality and woodland fires leading to soil erosion. In the semi-arid areas there is soil erosion of irrigated fields and intensified gully erosion in croplands and rangelands. Salinization of a large scale is expected due to expanding areas of agriculture irrigated with non-desalinated treated wastewater. Thus, rather than generating security problems due to desertification, the attempt to avert security problems by intensified development, eventually lead to desertification.

INTRODUCTION

In this chapter desertification is dealt with as a response of dryland ecosystems to pressure of dryland development, and is therefore a manifestation of non-sustainable development. The pressure constitutes an attempt to over-exploit the ecosystem service of biological productivity for generating subsistence crops. The pressure increases with reduced aridity of the drylands, whereas the vulnerability to desertification increases with aridity. These contrasting trends across the global aridity gradient place drylands of intermediate aridity, like those common within the Mediterranean basin under the greatest risk of desertification. Desertification and poverty are interlinked, culminating in land desertion and trans-boundary, mostly south-north migration which is often regarded as a "soft" security risk.

It is proposed that under current demographic trends land uses for traditional pastoral and farming livelihoods in drylands of intermediate aridity are bound to be risky. Therefore, alternative livelihoods that decrease rather than increase the exploitation of drylands' soil-based biological productivity yet are economically more profitable in drylands than in non-drylands, should be sought. These may be dryland afforestation for generation of firewood and income derived from carbon sequestration; cash-crop agriculture based on maximizing water use efficiency and minimizing land use, and capitalizing on winter warmth; dryland aquaculture capitalizing on drylands' light, warmth and fossil water reservoirs; and urban livelihoods based on the tourist- and solar-energy industries, capitalizing on drylands scenic and climatic attributes. These practices combined have the potential to arrest the north-south Mediterranean migration and replace it with a north-bound movement of cash crops and solar power, and a south-bound movement of tourists as well as finances linked to carbon trading, under the auspices of the Kyoto Protocol.

THE INTERLINKAGES BETWEEN DEVELOPMENT, DESERTIFICATION AND SECURITY

The UN Convention to Combat Desertification (UNCCD) implicates "various factors" as causing desertification (Article 1 of the UNCCD). The UNCCD is an offspring of the UN Conference on *Environment* and *Development*, and is habitually grouped with the "Rio" and the "Environmental" international conventions. It may be therefore timely to explicitly highlight the accumulating evidence that supports the description of *desertification* as a reaction of dryland *environment* (or ecosystem) to *development*; there are development projects and practices that do not generate desertification, but most desertification cases are tightly interlinked with dryland development.

This environmental response is driven by people striving to produce *essentials* for human livelihoods – food, fibers and forage, by exploiting a major service of dryland natural ecosystems – land, or biological productivity (Millennium Ecosystem Assessment, 2003). Dryland development is characterized by the intensification of this exploitation, forcing the ecosystem to *increase* the provision of the service of biological productivity beyond its natural provision rate. However, this attempt often achieves in drylands the opposite result – the provision of biological productivity not only does not increase, but it *declines* to a level below that prevailing prior to the onset of development. This man-induced time-lagged reduced provision of the service of biological productivity, its causes and its repercussions, jointly constitute the phenomenon of desertification. Thus, the first signs of desertification serve as an indicator that the threshold between sustainable and non-sustainable dryland development has been crossed.

Once their land becomes desertified, people desert the land and migrate (Middleton and Thomas, 1997). The term *Migration* is used here in its broadest sense; people can migrate to another plot within their lot, or another location or region within their homeland, and set in motion the train of events that had lead to the desertification of the land of their first choice. Only this time the downward spiral to desertification is much faster than the one experienced by the already desertified land. This is because the land of second choice is of biological productivity inherently lower than the one of first choice, and hence more vulnerable. Thus, sooner than later, the people take to a more dramatic, *cross-boundary* migration. Here too, the term is used in its broadest sense: migration through the rural – urban boundary; through socio-economic boundaries; and culminating in migration through ethnic, national and political boundaries. These cross- boundary migrations driven by the decline in provision of the dryland ecosystems' service of biological productivity, makes desertification to snowball from an environmental biophysical phenomenon to a societal security issue. These are often expressed in social, ethnic and political strife that further increase the demand for biological productivity (Figure 1).

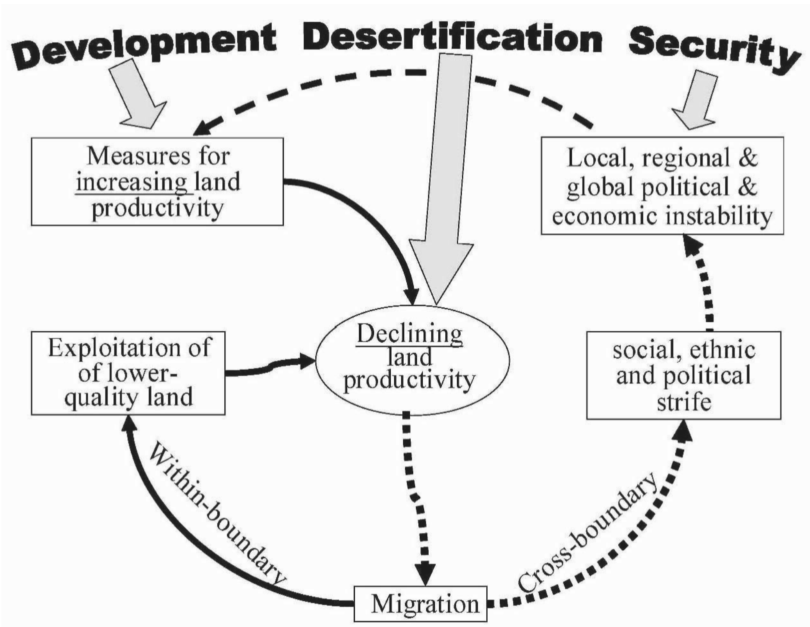

Figure 1. The desertification vortex: development (left-hand boxes) driving desertification (solid arrows, central circle), which generates security issues (dotted arrows, right-hand boxes), which drive intensified development (broken arrow) and further desertification

The dominant feature of drylands is their inherently low rate of provision of the service of biological productivity, hence having relatively low land productivity. This service can be exploited sustainably, but where populations grow in numbers or in per-capita consumption, the threshold from sustainable exploitation to non-sustainable one, hence to over-exploitation, is somewhere crossed. It is conceivable that due to the ecological constraints of drylands, their development is bound to cause desertification and become non-sustainable. It is therefore advisable to refrain from *increasing*, but to subscribe *reducing* the production of essentials; the temporarily reduced income may then be augmented by adopting livelihoods that are alternative to the ones farming and the pastoral livelihoods that capitalize on the provision of the service of biological productivity.

WHAT IS SPECIAL ABOUT DRYLANDS?

Dryland ecosystems differ from non-dryland ones by their low productivity, derived from a low ratio of rainfall to evaporation, namely, low rainfall and high evapo-transpiration, resulting in low soil moisture. This is often exacerbated by the uni-modality of the rainfall, resulting in a long period during which soil moisture depletion with no restoration prevails. The low productivity generates a relatively low plant biomass, which produces only small amounts of plant litter. This results in low soil organic contents. Many of the soil organic molecules enhance soil water holding capacity; hence the low soil organic content further reduces soil moisture, and productivity. Soil microbial activity instrumental in transforming the organic matter into plant mineral nutrients is soil moisture-dependent. Hence, low soil moisture constrains productivity by denying plants of two limiting resources – water and nutrients (Safriel, 1999).

The low soil microbial activity and the low organic content of the soil reduce the complexity of soil structure and the degree of soil development, and leave only thin relatively fertile topsoil. This thin topsoil is vulnerable to erosion, the first most significant expression of desertification. Thus, precipitation and radiation-induced evaporation jointly and directly drive a linear sequence of biophysical processes in which two negative feedback loops are embedded, that results in a vulnerability to dryland soil erosion (Figure 2).

The same two bioclimatic factors that are drivers of vulnerability to erosion are also drivers of vulnerability to salinization. The low precipitation results in a shallow soil penetration and hence the shallow moisture storage is susceptible to fast evaporation. This precipitates the salinity in raindrops, small as it may be, in the topsoil where it slowly accumulates. The low rainfall has a low capacity for leaching the shallow-deposited salts into deeper soil layers, down below the root zone of plants, thus making dryland topsoil vulnerable to salinization, the second most significant expression of desertification (Figure 2).

The degree of vulnerability is determined by the magnitude of the ratio between the bioclimatic drivers, the ratio between water input (precipitation) and water output (evapotranspiration). This ratio, the "aridity index" (Middleton and Thomas, 1997), together with soil physico-chemical properties, determines the amount of soil moisture available for biological productivity. The smaller this ratio, greater is the vulnerability to desertification.

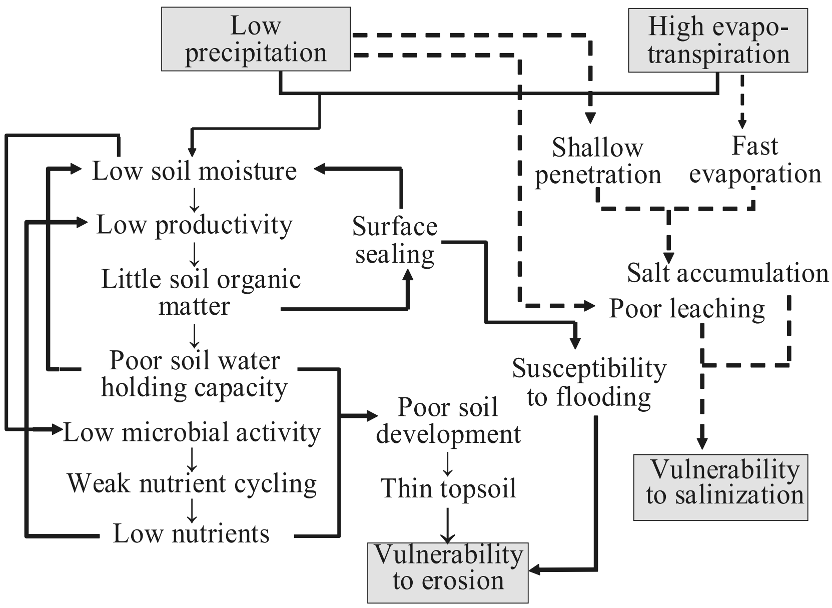

Figure 2. Biophysical drivers of vulnerability to desertification. Bioclimatic drivers (top boxes) of drylands' vulnerability to development (bottom boxes). Solid arrows – two negative feedback loops leading to vulnerability to erosion; broken arrows – chain of processes leading to vulnerability to salinization

WHEN WILL THE VULNERABILITIES MATERIALIZE?

It is often population growth and increased aspirations for elevated standard of life that drive further development, expressed in an intensification of exploitation of the drylands' ecosystem services. This intensification is amplified when it coincides with bioclimatic events, mainly droughts, which temporarily but drastically reduce soil and plant productivity. The intensification is expressed in an increase in the number of livestock and in spatial expansion of agriculture and adoption of intensive framing practices. Vegetation cover of rangelands becomes further reduced due to livestock grazing and human exploitation of vegetation for energy production and/or for medicinal and herbal uses. These land uses turn into overgrazing and overexploitation, respectively, when the rate of depletion of plant material exceeds regeneration rates. The resulting loss of vegetation cover increases the vulnerability of the soil to erosion, to the point of materialization of this vulnerability. Rangelands' soil erosion further reduces soil and plant productivity, and drive an intensified exploitation of the rangeland. Eventually the reduced level of forage production leads to the abandonment of the range, and/or to its conversion to cropland (Figure 3).

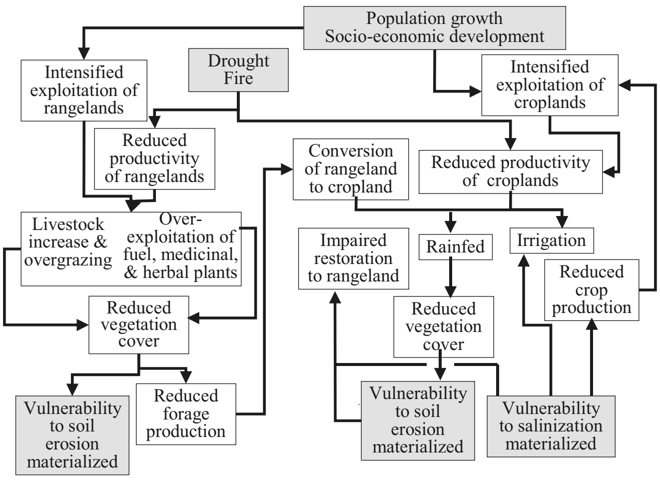

Figure 3. Desertification - materialization of vulnerabilities (bottom hatched boxes) driven by bioclimatic and anthropogenic drivers (top hatched boxes) in rangelands (left) and in croplands (right)

Croplands in drylands have lower productivity than croplands in non-drylands, and farmers attempt to subsidize their croplands with additional resources, mainly water. If this is not affordable, rainfed dryland croplands are fallowed during the lengthy dry season, and during dry years. This leaves the cropland devoid of vegetation cover, with an ensuing materialization of the vulnerability to soil erosion. Rainfed croplands then are either abandoned or converted to irrigated croplands. Irrigation indeed increases productivity and maintains vegetation cover, hence protection of the soil from erosion. However, irrigation accelerates soil salinization due to the often-high salinity of drylands' available irrigation water, and due to the farmers' inclination to save this expensive resource and not use it for leaching.

Thus, the vulnerability of dryland soil to salinization materializes in dryland-irrigated croplands, and this salinization directly affects plant growth. Depending on local circumstances, soil salinization may lead to groundwater salinization, and if irrigation water is derived from local groundwater, the downward spiral of low productivity is further intensified. Furthermore, salinization results in sodification that promotes materialization of the vulnerability of cropland soils to erosion. The reduced productivity of the croplands further intensifies cultivation; until both soil erosion and soil salinization reduce productivity to the point that land has to be abandoned.

At this point the soil may be irreversibly degraded, either due to topsoil loss, salinisation, or both, such that the range's biodiversity cannot be naturally restored, and it cannot revert to its original, traditional and sustainable use as rangelands. Thus, degraded rangelands that had been converted to croplands become degraded too. Even the removal of the degrading drivers cannot restore these lands such they either become productive croplands or function as productive rangelands. The land is then deserted, and people are forced to abandon both the pastoral and the farming livelihoods.

WHERE HAVE THE VULNERABILITIES MATERIALIZED?

It follows from the previous discussion that drylands' vulnerability to desertification should increase with aridity, and hence the sensitivity of drylands to development, being a major driver of desertification, should also increase with aridity. Using the values of the aridity index (Middleton and

Thomas, 1997), the global aridity gradient ranges from 0.65 (potential evapotranspiration, i.e. potential loss of soil moisture, is ca. 1.5 greater than precipitation) down to values lower than 0.05 (i.e., atmospheric demand is more than 20 times greater than water input). Using UNEP's classification, this range is subdivided into four dryland categories that express a global aridity gradient, from the least dry dryland and hence the least vulnerable – the dry subhumid, through the semiarid and arid, to the most vulnerable, the hyperarid dryland (Middleton and Thomas, 1997).

Thus, it is expected that whereas a mild development pressure may not degrade the productivity of a dry subhumid ecosystem, the same pressure will degrade the productivity of a semiarid one. Since the productivity of drylands declines with their aridity, so is their appeal to people and attractiveness to development. It is therefore expected that human population density and the associated density of livestock will decrease with aridity; hence their combined environmental impact will decrease with aridity too. It follows that where vulnerability is greatest, development pressure is lowest, and vice versa. Hence, the degradation of biological productivity of drylands, i.e., desertification, is a function of the product of vulnerability and development pressure. If both vulnerability and pressure are linear functions of aridity, degradation as a function of aridity should follow a hump-shaped curve peaking at the center of the aridity gradient. When vulnerability declines linearly but development pressure increases exponentially with aridity, the degradation curve should be biased to the low aridity section of the gradient; namely, – the peak is closer to the semiarid than to the arid section of the gradient, and the dry subhumid degradation is higher than the hyperarid degradation (Figure 4a).

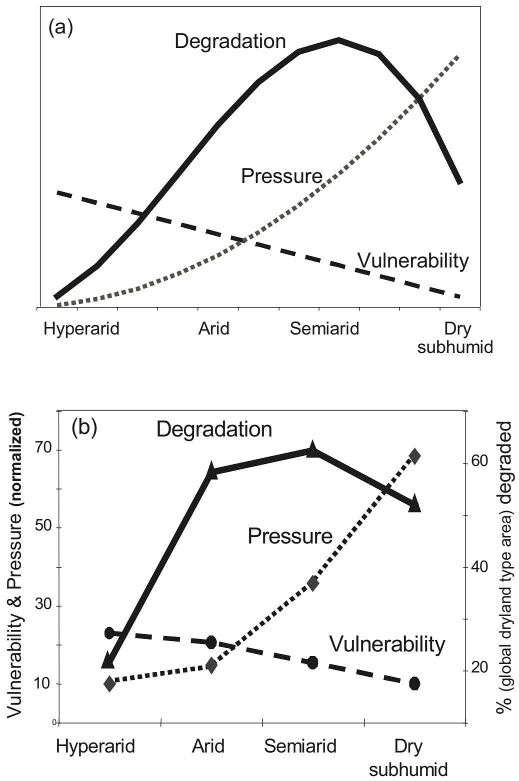

Figure 4. The combined effect of development pressure and dryland vulnerability on desertification across the global aridity gradient. (a) Model prediction – degradation is the product of vulnerability and pressure; (b) Observations: Vulnerability expressed as [1-(median of Aridity Index range values for each dryland category)]; Development pressure is expressed by human population densities (number of people/sq km, CIESIN, 2004); lowest value normalized to 10; Degradation is "high" land degradation area (GLASOD, 1990), expressed as percentage of global area of the dryland category; lowest value normalized to 10

Therefore, the degradation of drylands when categorized by their aridity level can be described by a humped shaped curve along the aridity gradient, with a peak at the central section of the range. Thus, semiarid and arid ecosystems, and especially the transition between the two, are expected to be moderately vulnerable and to be driven by an intermediate development pressures, a combination that generates the most severe degradation i.e., desertification.

Indeed, human population density expressed as number of people per km^2 for each of the four global dryland categories decreases exponentially with aridity. Degradation of biological productivity, expressed in the percent of global dryland category affected by severe land degradation, demonstrates a hump-shaped curve of a form predicted by the model (Figure 4b). It is therefore likely that dryland vulnerability indeed increases with aridity, hence areas with values of aridity intermediate between semiarid and dry subhumid aridity values, are most prone to desertification.

WHERE ARE THE MEDITERRANEAN DRYLANDS?

The Mediterranean basin comprises a transition between southern desert (Saharan-Arabian deserts) and northern non-desert (European woodlands). Using UNEP's classification, the political boundaries of all Mediterranean countries include the whole range of dryland categories: from south to north, southern Mediterranean countries which are closer to the Sahara-Arabian deserts than the northern Mediterranean countries, have hyperarid drylands (true deserts), semiarid drylands, and dry-subhumid drylands; north Mediterranean countries have semiarid drylands, dry-subhumid drylands, and non-drylands regions – humid areas.

The UNCCD does not regard hyperarid drylands as prone to desertification, hence all Mediterranean countries have within their boundaries areas prone to desertification and areas not prone to desertification; in the southern Mediterranean countries the southern-most and driest regions are not prone to desertification and in the northern Mediterranean countries – these are the northern-most and least dry regions. The European and/or the northern parts of the Mediterranean basin do not have arid and hyperarid drylands. In the south-eastern parts of the basin these dryland subtypes do appear and become widespread with increasing distance from the coast (the transition between semiarid and arid drylands occurs between 260 to 720 km due south of the Mediterranean coasts of North Africa, whereas in the south-eastern Mediterranean arid drylands often appear close to the coastline).

Thus, most drylands of the Mediterranean basin are semiarid and dry subhumid drylands. Namely, drylands that at least part of their extent are characterized by a degree of aridity that is most prone to desertification, on account of both its moderate vulnerability impacted by moderate human population pressure. Indeed, the Mediterranean basin has experienced desertification during its lengthy history of extensive and intensive land use. Experiences accumulated during the millennia of combating desertification, and more recent advances in agricultural research have been and still are counterbalanced by population growth, though there are some very recent positive trends (Thornes, 1998).

As in many other global drylands, the downward spiral of land productivity in the Mediterranean basin that ends up in desertification is not driven only by population pressure coupled with the degree of aridity. Rather, it is also augmented by shortage of financial resources and institutions that are critical for arresting or avoiding this spiral (Mazzucato and Niemeijer, 2000); aridity and poverty go hand in hand also in the Mediterranean basin, and their joint trajectory is from north to south, as well as from west to east. However, it is often difficult to trace whether poverty and its associated security issues, is generated or is driven by desertification.

THE ROAD TO DRYLAND SUSTAINABILITY - ALTERNATIVE LIVELIHOODS

In spite of an increasing number of success stories (e.g., Middleton and Thomas, 1997), the emergence from poverty in the drylands has in many cases been unsuccessful, which catalyzed the adoption of the UNCCD by a majority of countries. It is likely that under the current global, as well as the Mediterranean population pressures, the pastoral and farming land uses cannot be sustained by dryland ecosystem services. Efforts to promote dryland services for sustaining population growth and elevated standard of living in the Mediterranean basin require inputs and subsidies, mainly those of transported water, which may be more expensive than outputs (e.g., National Research Council, 1999; UNCCD, 2002). Livelihoods that are subsidies-dependent cannot be regarded sustainable, and when subsidies are curtailed, desertification reappears. Thus under current circumstances efforts to intensify the drylands' services of biological productivity are bound to perpetuate, rather than eradicate poverty.

Therefore, rather than striving to somehow and somewhat improve the lot of dryland rural population by grappling with the drylands' natural inherently low biological productivity for generating respectable and sustainable livelihoods, it may be more productive to look at other ways of exploiting the drylands' ecosystems; ways that do not attempt to increase the provision of services, but to exploit ecosystem functions that may even serve people in drylands *better* than in non-drylands. Namely, they may enable dryland people to be better off than non-dryland people, rather than perpetually lagging behind them in income and well-being.

Water limitation and degraded capacity of the land to produce, further exacerbated by socio-economic and political constraints, recently drive dryland people to experiment with a plethora of livelihoods, termed "alternative livelihoods". These emerging livelihoods are not dependent on traditional land uses, and they are economical on land- and natural resource use.

Alternative livelihoods are (a) less dependent on the ecosystem service of biological productivity than other dryland livelihoods; (b) do not impair the provision of ecosystem services; and (c) generate more income per investment of local dryland resources, as compared to the traditional, biological productivity-dependent livelihoods, and (d) are of potential to provide their practitioners a competitive edge over those who practice them outside the drylands. These livelihoods will be now discussed, in order of decreasing dependence on dryland ecosystem services, and hence of decreasing desertification risks and increasing likelihoods of sustainability.

Dryland Afforestation

In both natural and cultivated drylands the share of the tree life-form in the vegetation generally decreases with aridity, due to the tree-required deep and large soil moisture storage that can not be guaranteed as aridity increases. Sylviculture and rainfed horticulture are therefore not commonly practiced in drylands; when practiced sylviculture, and especially horticulture, depends on labor-intensive construction and maintenance of runoff-harvesting structures (Evenari *et al.*, 1982; Droppelmann *et al*., 2000). However, dryland sylviculture and horticulture provide better soil protection than agriculture. This is because tree canopies are denser and tree root system is deeper and more extensive than those of agricultural crops; and also because unlike agricultural crops of which very little is left to cover the soil after harvest, trees fully function in soil conservation also after harvest of their fruit crop. Yet, the incidence of orchards declines with aridity, due both to water constraints and the paucity of dryland domesticated fruit tree species. At the same time, the demand for bio-fuel that increases with the increasing dryland population is one of the major drivers of desertification resulting from the removal of vegetation cover used for fuel (Sauerhaft *et al*., 1998).

Firewood Production

Dryland sylviculture for firewood production may therefore be an effective measure of combating desertification. However, like dryland subsistence agriculture, dryland sylviculture too attempts to promote the service of biological productivity to a level much higher than natural, and hence may lead to eventual desertification. Yet, management of sylviculture, or afforestation, for sustainable yield of firewood and at the same time for a sustainable provision of the service of effective soil conservation, is advantageous over dryland agriculture. This is because the forest conserves the soil on which it has been planted, and at the same time the use of its "crop" reduces human pressure on the natural vegetation, and thus helps maintain the provision of forage on the one hand, and the conservation of soil outside the forest. Thus, dryland afforestation for firewood production is a livelihood that depends on the biological productivity service of dryland ecosystems, yet rather than generating desertification; it reduces desertification at a spatial scale much greater than that occupied by the forest itself.

Carbon Sequestration

Dryland sylviculture for firewood production may be more productive and is undoubtedly less desertification-prone than dryland agriculture. But it qualifies as an alternative livelihood if it generates more income than non-dryland sylviculture. The carbon sequestration service of forests and their contribution to the above- and below ground carbon reserve, and the recent emergence of "carbon trading" under the Clean Development Mechanism (CDM) brought forward by the Kyoto Protocol of the UN Framework Convention on Climate Change (UNFCCC), may make the required difference. This is because most non-dryland ecosystems with the best provision of the service of biological productivity are either used for food, fiber, forage, and timber and firewood production. Namely, they are either cultivated or afforested. On the other hand, though the global drylands are less efficient than non-drylands in carbon sequestration, their potential for further carbon sequestration is high (may reach about half of the annual anthropogenic enrichment of the atmosphere) and is hardly materialized (Table 1), while the potential of the non-dryland one is already close to full materialization.

Table 1. The drylands' estimated potential for carbon sequestration by restoration (e.g. of degraded lands) and by enhancement (e.g. afforestation), compared with the current global annual atmospheric enrichment (adapted from Lal, 2001)

Strategies	Potential sink function (PgC/y)
Restoration of C reserve	0.4 – 0.6
Enhancement of C reserve	0.5 – 1.3
Total	0.9 – 1.9
Global enrichment	3.3

The experience of afforestation of a degraded semiarid rangeland in Israel is promising: a forest of *Pinus halepensis,* fed by 270 mm mean annual rainfall and located at the periphery or even beyond this species' range, exhibits a sink function of 165 gC/m^2/yr (as compared to an average of global monitoring network's dataset [FluxNet] of 270 gC/m^2/yr), and its mean annual addition to the carbon reserve during the 35 years since planting is 150gC/m^2/yr, is therefore storing twice as much carbon as the adjacent non-forested rangeland (Gruenzweig *et al.,* 2003).

Due to the high potential for Carbon sequestration, the income from firewood production of such dryland afforestation projects can be augmented by income from carbon trading under the CDM (TERI, 2000): UNFCCC Annex I (developed) countries may finance afforestation projects in non-Annex I (developing) countries. This may make dryland afforestation used for both firewood production and carbon sequestration, more profitable than non-dryland afforestation, and thus constitutes a dryland, non-degrading alternative livelihood (UNCCD, 1999).

Controlled Environment's Cash Crop Agriculture

Dryland sylviculture exploits the ecosystem service of biological productivity though not for producing subsistence crops. Similarly, there are dryland agriculture practices that can qualify as alternative livelihood, ones that may be even less dependent than sylviculture on the services of dryland natural ecosystems. These derive from the engagement of plastic covers in agro-technology. The plastic cover allows nearly full light penetration, and at the same time provides options for locally manipulating many other crop-relevant environmental factors (Arbel *et al*., 1990). This practice ranges from covering individual rows of low stature crops, with no additional intervention and for only a part of the growing season, to including plots within "growth houses" or "greenhouses". The latter accommodate crops as high as a person's stature and even more, and maximize the detachment of the crops from the outer dryland environment, by controlling several of the internal environmental conditions.

The gradation in detachment from the ambient environment follows the aridity gradient – the need as well as the benefit of detachment, i.e., artificially creating an environment that differs from the dryland natural one, increases with aridity. The primary motivation for a plastic cover is that it reduces evapotranspiration, hence water use efficiency can be maximized (Pohoryles, 2000), and its benefit increases with increased aridity. Furthermore, insecticide use is dramatically reduced, and carbon-dioxide fertilization becomes feasible. Often the crops are grown on artificial substrates, nutrient are provided by fertilization, water is provided by irrigation, and even pollination is provided by commercially produced and marketed pollinators (BioBee, 2000). These combined enable intensification of biological productivity. This productivity utilizes the free, local incident light, but it is totally independent of services provided by the local ecosystem. The resulting efficiency is not only in water use but also in land use; hence this practice relieves the pressure on land resources. Provided that it does not deplete local water resources, this practice does not have the potential to cause local desertification.

On the other hand, the practice is very costly – though it saves land and especially water, investment in infrastructure and in operation costs, which may include energy for ventilation and cooling, are high. The intensification generates more yield per unit of investment, but the crops must be highly valuable, namely – cash crops. The production of cash crops in drylands may be more profitable than in the non-drylands, on account of two physical/climatic virtues of many, though not all drylands – high irradiation due to relatively low overcast, and higher ambient winter temperatures relative to those prevailing in the nearest non-dryland areas. Indeed, the gross value added and the cash output per unit area of that part of the hyperarid dryland of Israel in which intensive greenhouse agriculture is widely practiced, is higher than those of all other types of Israeli agriculture, including those of the least dry areas – the dry subhumid ones (Portnov and Safriel, 2004).

Aquaculture in Drylands

Dryland aquaculture is inherently advantageous on dryland agriculture. This is, paradoxically, due to the water scarcity, or more precisely, to the high evaporative losses that make an area a dryland; though aquatic organisms live in water, they don't transpire water, hence water losses from aquaculture can be analogous to evaporation, rather than to evapotranspiration. Furthermore, many more aquatic than terrestrial crop species are tolerant to salinity in water and even benefit from it. Thus, dryland aquaculture can thrive on fossil aquifers, that though quite common in drylands their salinity greatly curtails their usability by dryland agriculture.

When dryland aquaculture borrows the technology of dryland greenhouses described in the previous section, water conservation is greater than it is in agricultural greenhouses (due to zero transpiration of aquatic organisms), and at the same time dryland aquaculture does not compete on water with dryland agriculture, due to the divergent salinity tolerances of terrestrial plants and aquatic organisms (Koren and Alon, 2004). Since dryland aquaculture is always more economical on land than dryland agriculture, then not only its water- but also its land-use efficiencies are high. Thus, dryland aquaculture, just as dryland cash crop agriculture, does not depend on local ecosystem services, and does not cause desertification.

Dryland aquaculture can be based either on animals or on plants (mostly micro-algae), or on their combination. Unlike plants, the productivity of aquatic animals (fish and crustaceans) is not light- and carbon dioxide- dependent, and hence the costs of feeding the animals are greater than that of fertilizing the plants. There is, however, an added cost of water - the enrichment of the water by the organic load of feed surplus and animal excretions requires water filtration. This cost can be much reduced by integrating animal and plant aquaculture, in which algae thrive on the animal-enriched water. Or, the enriched water can be used for irrigation of crops.

Plant aquaculture is advantageous on animal aquaculture in that being autotrophs, feed input for aquatic plants is much reduced as compared to aquatic animals, and hence organic load is not a problem. Plant aquaculture is also advantageous on agriculture since most aquatic plants are either very small or unicellular (mostly algae), their growth is much faster than that of terrestrial plant crops, and the ratio of harvested to non-harvested biomass of the crop is much higher than that of terrestrial plants.

Dryland aquaculture of both plants and animals are advantageous on non-dryland aquaculture, by virtue of the abundance of light (for aquatic plants; Richmond, 1986) and of winter warmth (for both plants and animals; Kolkovsky *et al*., 2003). An added benefit is the higher availability and hence the lower price of land in the drylands than in non-drylands, and the reduced competition with agriculture on land, between dryland and non-dryland aquaculture. Most of the products of dryland aquaculture are cash crops, such as ornamental fish, high quality edible fish and crustaceans, and industrially valuable biochemicals produced by micro-algae, such as pigments, food additives and pharmaceutical products. Finally, unlike coastal aquaculture that generates environmental problems and its sustainability is dubious (Nayler *et al*., 1998), dryland aquaculture is environment-friendly and of potential for sustainability.

Urban Livelihoods

Though "dryland development" and "rural development" are often synonymously used terms, dryland cities as an alternative to dryland villages may prove to be a sustainable option for settling more people in drylands. Dryland urbanization may be advantageous, both over other land uses in drylands and over urbanization in the non-drylands. This is because dryland cities consume and hence impact fewer land resource than the drylands' farming and pastoral livelihoods, and have a lower environmental impact than non-dryland cities. The prevailing notion of drylands is that of harsh climate and meager livelihood opportunities, hence the success of dryland cities depends on their ability to provide livelihoods as well as living conditions that are advantageous on those provided by non-dryland cities.

Sustainable living conditions in dryland cities

All drylands are very hot in summers and many are very cold in winters, and are therefore expected to require expensive investments in energy expended on climate control. This may be a wrong approach to dryland urbanization; a combination of appropriate building materials, architectural design (Etzion *et al*., 1999) and urban planning (Pearlmutter and Berliner, 1999) can provide living conditions in drylands that are as comfortable as and much cheaper than those provided by non-dryland cities.

This is because drylands are endowed with two climatic features that are highly conducive for "passive", i.e. energy saving climate control. The very low air humidity in many drylands makes summer evaporative cooling very efficient and cost-effective. The low dryland overcast enables the dryland solar radiation, combined with appropriate positioning, dimensions and technological design of glass windows (Etzion and Erell, 2000), to provide efficient and cost effective winter warming.

Thus, the use of fossil fuels for cooling and fossil or biomass fuels for warming can be far lower in dryland than in non dryland-cities. Furthermore, though there is an added transportation cost of providing fossil energy to dryland cities due to their relative isolation, the fossil energy can be nearly completely replaced by solar energy-generated power (Faiman, 1998). This is feasible due to the high year-round intense solar radiation coupled with the low overcast in drylands. Finally, another advantage of dryland cities over non-dryland ones is the cost of land, which decreases with increase in aridity and the associated decrease in human population size.

Dryland tourism as urban alternative livelihood

Like elsewhere, the development and availability of urban livelihoods in the drylands depends on social and economic processes and policies. But drylands can generate at least two urban livelihoods that constitute alternatives to traditional dryland livelihoods yet engage in exploitation of attributes unique to drylands. These are the already emerging dryland tourist industry that capitalizes on the touristic appeal of many drylands, and the solar energy-generating industry that will capitalize on the forecasted increasing demands for reducing emissions of greenhouse gases coupled with the high potential of drylands to generate economically-viable solar-based alternatives to fossil energy.

Several global trends invigorate the dryland tourism industry (Diamantis, 1998). These are the increasing affluence, free time and motorization coupled with the growing craving for non-congested, non-polluted, pastoral, and pristine and wilderness landscapes, entertained by a relatively large segment of the global human population. This is further augmented by the growing publicity of the scenic, wildlife, biodiversity, historical, cultural and spiritual assets that are unique to many drylands, and which dramatically enrich the quality of recreation in the drylands. This population, however, does not compromise on comforts and other leisure-time amenities while on vacation. This is why drylands' well developed urban centers are the prerequisite for exploiting the recreational services of dryland ecosystems. Employment in the tourist industry may then become the major dryland urban alternative livelihood.

Though urban dryland livelihoods are economic on land use, their impact on dryland water resources requires attention. Given the large water demand of dryland agriculture, the per capita water demand of a dryland city is likely to be lower than that of dryland village. But the tourist industry is a significant consumer of water. Irrespective of dryland urban *vs*. dryland rural development, the growing demand *vs*. the diminishing supply of renewable water in the drylands catalyze an intensified improvement of technologies for increasing re-use of wastewater and for water desalination in drylands (National Research Council, 1999). These are likely to respond to the water demand incurred by the dryland tourist industry; hence dryland and non-dryland cities engaged with the tourist industry may share water-related problems as well as solutions.

However, a dryland city may have some water-related advantages over non-dryland city (Ben-Zvi, 2001; Gat, 2001). In non-drylands and least dry drylands it is the soil-penetrating rainfall water rather than the surface runoff water that recharge groundwater. In drier drylands much of the soil-penetrating rainfall water evaporates hence the relative contribution of surface runoff to groundwater recharge is greater. When a non-dryland ecosystem is converted to an urban one, the soil-surface sealing brought about by urban development dramatically reduces groundwater recharge. Or, the recharge is not by soil-penetrated clean rainfall water, but by the runoff generated by the city's sealed surface, that when reaching groundwater is already heavily loaded with pollutants. On the other hand, dryland cities, especially those in the drier drylands, do not deplete but increase groundwater reserves. This is because surface sealing of these dryland cities transforms rainfall water that would have otherwise been lost to evaporation, to surface runoff, that can significantly add to groundwater recharge. Provided that dryland cities take care to prevent pollution of this city-surface runoff, high rainfall use efficiency is achieved by dryland urbanization.

Solar Energy Generation as Dryland Alternative Livelihood

Solar Power plants that have been of marginal interest to mainstream energy producers are likely to play a bigger role in power generation for both environmental and security reasons. The world's drylands are sufficiently large that, in theory, covering a fraction of their landmass with Photovoltaic systems could generate many times the current global energy supply. The efficiency of solar power generation increases with aridity, both due to the incidence of solar radiation and the availability of vast, cheap land areas. It was calculated, for example, that 4% of global desert area (hyperarid and arid drylands) used for Very Large Scale Photo Voltaic power generation plants, can produce an annual energy production that would equal world energy consumption, at an attractive cost, and while providing thousands of jobs (Kurokawa, 2003).

The economical value of this clean and renewable energy source will gradually but dramatically increase as the detrimental effects of the anthropogenically-induced global warming, coupled with the inevitable depletion of fossil fuel reserves, will become apparent. These prospects are bound to intensify the improvement of technologies that make dryland solar energy a commodity produced, used locally as well as exported. Mediterranean dryland cities may then serve the solar energy-related industries, which will add to their sustainability as foci of dryland urban alternative livelihoods.

NORTH-SOUTH EXCHANGE WITHIN THE MEDITERRANEAN BASIN

The current flow of immigration within the Mediterranean basin is unidirectional – the geographical South-North migration from North Africa to Europe, as well as from the "socio-economic south", which is actually from the east (mainly Turkey), to Western Europe (Leontidou, 1998). At least in part, a substantial segment of this immigration is driven by loss of food- and environmental-security linked to desertification; This immigration then drives apparent or even tangible "soft" security concerns in the target countries, some of which are themselves desertification-affected countries.

Attaining sustainability of dryland development, through relieving much of the pressure on the service of biological productivity of dryland ecosystems by replacing them with alternative dryland livelihoods, will reduce immigration and increase security within the Mediterranean basin. The desertification-driven unidirectional migration will be replaced by mutual exchanges.

Two South-North flows can be envisaged. One is that of cash crops produced by intensive but low-impact agriculture as well as aquaculture products. The other one is that of transported solar energy generated in southern Mediterranean arid drylands that may provide a tangible segment of the North's energy demand. At the same time two North-South flows can be anticipated. The first is that of finances for afforestation CDM projects of Northern Mediterranean Annex I countries carried out in non-Annex I countries of the Southern Mediterranean basin. The second is a flow of people: the unidirectional South-North flow of migrants will be replaced by the North-South flow of tourists going the opposite direction. These will drive the development of dryland tourism supported by sustainable dryland urbanization and accompanied by the conservation of landscapes recovered from desertification and available for recreation and other non-degrading uses.

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STATE OF NATURAL RESOURCES DEGRADATION IN MOROCCO AND PLAN OF ACTION FOR DESERTIFICATION AND DROUGHT CONTROL

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INTRODUCTION

Severely stricken by successive periods of drought, Morocco has made desertification control, drought mitigation, and environment protection, in general, top priorities in its socio-economic development.

Efforts undertaken by Morocco to control desertification are both important and multi-facetted and are carried out on many fronts. Many plans, strategies and programs have been developed recently and cover the main fields of development, natural resources protection and the socio-economic equipment of the rural world: drinking water, electrification, rural roads, improving affordability to basic education, irrigation, watershed management, rangeland management, development of rainfed agricultural areas, and sites of special biological interests.

In order to overcome the natural hazards and meet their basic needs, the populations continue to depend on natural resources substantially. They often resort to irrational practices, such as deforestation, overexploitation of lands and pastures, which are, in many ways, contrary to a vision of a sustainable development.

Therefore, the purpose of the present paper, includes the main actions and the approach developed in the Moroccan National Action Plan to combat desertification, which recognizes the importance of putting populations at the forefront of any activity whose purpose is to redress the

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land degradation trends in the areas and also underscores the importance of adopting a participatory approach in addressing these issues.

STATUS OF NATURAL RESOURCES, CAUSES AND SCOPE OF DEGRADATION

The Kingdom of Morocco extends over a surface of about 710.850 km² and has 3.500 km of coasts along the Atlantic Ocean and Mediterranean Sea. The four mountainous chains of Anti Atlas, High Atlas, Middle Atlas and Riff confer a geographic diversity. The Mediterranean climate prevails over much of northern and central Morocco, and is moderated by the oceanic influence. Moving southward, the climate becomes increasingly hot and arid with important temperature differences. Over two-thirds of Morocco can be classified as arid and semiarid, with low and variable rainfalls and frequent droughts. In the period ranging from 1973 to 2003, only five wet years were recorded, namely in 1974, 1977, 1978, 1996 and 2003 (Ameziane et Ouassou, 2001). According to the 1998 census, the population is estimated to stand at approximately 28 million people and is growing at an average rate of 1.72 % per year. The rate of urbanization is currently around 54 % (AGR/DAF, 2001).

In Morocco, the problems of desertification due to natural and human factors are amplified by unsuitable systems of the available natural resources exploitation. This expressed as land and plant cover degradation leading to the decline of the productive resources which is the corollary of a degradation of population conditions in the arid, semi-arid and sub-wet zones and in a greater vulnerability in case of the least climatic crises.

The diagnosis of the prevailing systems of natural resources use reveals that the latter face immense difficulties in securing their renewal and sustainability. It also allows identification of a set of policy inconsistencies and dysfunctions, which prevailed continuously in the past and resulted in the degradation of the productive base of natural resources. Under certain conditions, they resulted in decreasing the productivity of some agrarian systems, leading to a drop in rural populations' incomes compensated by an ever-increasing pressure exerted on natural resources.

Land degradation indicators

The indicators of natural resources will be examined for each of the major ecosystems, whether natural or managed, prevailing in Morocco.

Natural ecosystem degradation

With regard to land degradation of natural ecosystems, it is worthwhile noting the overuse of natural resources and the rate and extent at which erosion is spreading. Out of 20 million Ha. of watersheds located upstream of existing or future dams, approximately five million Ha. face significant risks of water erosion. With an average soil loss over 2000 tons/km^2/year in the Riff region, Morocco belongs to the group of countries exhibiting the highest erosion rate (Merzouk, 1988; AGR/DAF, 2001).

Diagnosis of Moroccan forests shows quite a worrying degradation, resulting from the combination of excessive wood harvest, forest fires, crop encroachment and excessive harvest of fuel wood. Thus, forest decline is estimated at approximately 31.000 Ha. each year, the breakdown of which is as follows : 22.000 Ha. corresponding to fuel wood harvest, at a level far beyond the productive capacity of the forest, 4.500 Ha. resulting from land clearance, 3.000 Ha. lost to fire, and 1.000 Ha. to urbanization and other domestic uses (Karmouni, 1993; AEFCS, 1996).

Similarly, rangelands are subject to impoverishment of their vegetation cover. In this regard, approximately 8.3 million Ha. of rangelands are heavily degraded. They are located mainly in the eastern regions of Morocco (the Oriental), the Souss, the Pre-Sahara and the Sahara. Furthermore, land clearing affects more than 65.000 ha, taken from the best grazing lands of the country (AGR/DAF, 1999).

Managed ecosystem degradation in rainfed agricultural lands and in irrigated areas

Rainfed agricultural lands are constantly exposed to numerous forms of water and wind erosion, leading to loss in soil fertility and arable land. A comprehensive study conducted in 1973 concluded that out of 7.7 million Ha. of agricultural lands, which were concerned by the survey, 5.5 million Ha. were subjected to intense erosion (AGR/DAF, 2002).

Various forms of degradation including overexploitation of the water table also threaten irrigated lands and water pollution resulting from untreated domestic and industrial waste waters. Salinity is, however, the most visible expression of irrigated land degradation. It occurs in most Moroccan irrigated systems. Available data on salinity indicate that approximately 500.000 Ha. located mainly in the Regional Agricultural Development Office areas are threatened by salinity (Price, 1998; AGR/DAF, 2002).

The oasis is also threatened by salinity and blowing and drifting sand. A study, conducted in 1982 on 21.000 ha, revealed that 35 % of the Tafilalet palm grove soils were salty (4 to 6 g/l), and 18 % very salty (>16g/l). In addition, sand movement continuously threatens houses, agricultural lands, irrigation canals and roads. Affected areas are estimated at 30.000 Ha. in the Ouarzazate province and 250.000 Ha. in the Errachidia province (AGR/DAF, 2001).

Determinants of land degradation

The climate is the first determinant of land degradation. Its major characteristics are extreme variability, low rainfall, an average duration from 4 to 6 months, and cold wintertime, which in altitudes over 1000 m, is a real constraint for plant growth and development.

Scarcity and fragility of water and arable land resources contribute to their degradation through deepening the chronic unbalance between increasing population and available natural resources. In 1990, water availability per capita and per year was 1,151m^3. It is predicted that this quantity will drop to only 689 m^3/ per capita/ per year, in 2025. Similarly, arable lands will undergo the same constraints already affecting the water resources (Ait Kadi, 2002).

Natural resource degradation in Morocco is partially linked to the high population growth. In the rural world, the current population trend encourages the proliferation of unsustainable production patterns based on land use which is incompatible with its production capacity.

Other institutional and governance factors compound natural resources degradation at varying levels. The complexity of the multiple land tenure systems use in Morocco is often resulting in an insecurity feeling of users yielding some behavioral patterns related to short-term overexploitation and abuse of the land.

On the institutional and public policies levels, some incoherencies and dysfunctions are noted in the incentive measures implemented, so far. Uniform implementation of the provisions of the Agricultural Bank and the Agricultural Development Fund loan schemes (subsidies and loans, price support) throughout the country without proper consideration of ecosystem specificities has resulted in inadequate resource allocations. This has also generated some distortions in the production systems, promoting crop expansion at the expense of forest and rangelands, unsuitable for agricultural activities.

REVIEW OF STRATEGIES, PLANS AND PROGRAMS

Numerous plans, strategies and programs have been designed recently. Although some of these strategies and plans have not yet been translated into concrete actions, the process of their preparation has provided an opportunity for carrying out an in-depth and holistic reflection on establishing a diagnosis of the current situation, identifying constraints and defining new courses of action in connection with development.

Most of these designed plans, strategies and programs have a clearly defined sector-based dimension. Few are mandated with a horizontal mission aiming at ensuring an integrated type of development. Another category consists of a new generation of cross-sectional programs focusing on reducing the deficit accumulated by Morocco in terms of social infrastructure in rural areas. They fit within the objectives of giving substance to the policies related to poverty alleviation.

Integrated plans and programs

Chronologically, the oldest project whose objectives center on dealing with desertification problems is:

-*The DERRO program* that was launched in 1965 and adjusted in 1968. This program aims at contributing to the rural development of Western Rif and controlling erosion risks threatening this region. Actions undertaken within the framework of this project encompassed plantation of fruit trees, land development projects, herd management development, construction of earth roads, rehabilitation of springs and erosion control.

-*The Integrated development projects* (IDP): They consist of a project package prompted by the World Bank at the end of the 1970s.The PDI covered almost one million hectares, primarily in grain-cropped areas, and in places where extensive livestock production systems play an important role in the economy of existing farmsteads.

-*The national plan to combat desertification*: It was developed in 1986, in compliance with the recommendations of the International Conference on Desertification held in Nairobi in 1977. The plan focused on two priorities: rangeland management and supply of fuel wood. Specific projects were then suggested for each of these sectors and homogeneous zones were identified for project implementation.

Sector plans and programs

The master plan for management and conservation of rainfed drylands (i.e. bour) has particularly contributed to the enactment of Law number 33/94, which has become a basic policy instrument underlying public intervention outside irrigated schemes.

The National Irrigation Program (NIP) encompasses all the policy elements for state intervention in the irrigated schemes between 1993 and 2000. Re-appraisal of irrigated areas management seeks to achieve three basic goals: (i) expanding land under irrigation, (ii) water saving and initiating partnership schemes. The NIP grants a particular importance to small and medium-scale hydraulics.

The National Forest Colloquium held in Ifrane in 1996 was instrumental in developing sector-based strategies seeking to achieve a partnership-based sustainable development of the Moroccan forest. This strategy is built around five major axes: (i) patrimonial management of the forest; (ii) a long-term vision of forestry development; (iii) development of the peri-forestry areas; (iv) development of partnership schemes; and (v) revamping the financing system of the sector.

The national plan for watershed management was finalized in 1996. Its preliminary conclusions mainly concerned classifying watersheds on the basis of the degree of their erosion severity and defining appropriate approaches for watershed management. The plan provides also insights into the cost of inaction and its impacts on agriculture productivity, on dams' lifespan, and more generally on the country's social and economic development.

The plan for protected areas was developed in 1994. This plan identifies three priority categories in terms of planning the process of granting the label “protected area” to inventoried sites. Thus, the first group, consisting of 51 sites of biological and ecological interest (SIBE), will be labeled in the protected areas within five years from implementation of the status. The two other deadlines were set at eight and 14 years for 44 and 59 sites (SIBE), respectively. The plan integrates in its approach the expectations and concerns of populations, which are either riparian to or operators of the protected areas.

The reforestation plan was finalized in 1997, in conformity with the recommendations of the strategy for forestry development. Inspired by a long-term vision, this plan aims to meet in a sustainable way the core needs of forestry products of Morocco. Implementation of this ambitious objective will be achieved through developing partnership schemes involving the maximum of private and public operators with a view to speeding up the reforestation process and promoting participation to local programs on the basis of a participatory approach.

The strategy for rangelands development: The conclusions yielded by the studies, carried out on rangelands, highlight the fact that any rangeland development strategy should be the expression of a strong political will, providing concrete options to the sensitive issues of land tenure status, conditions of affordability with regard to the resource base and the production systems offered to pastoralists. This strategy challenges the principle of free of charge access to rangelands and to drinking water for animals. It also provides a contingency plan to facilitate implementation of an appropriate policy for adequately pricing access to rangeland resources.

The Oasis space: The National Plan for Restructuring and Development of palm groves was launched in 1987 and then later updated and prorogated for another nine additional years in 1998 to run until 2007.The plan proposes to reverse the trends of regression of the Moroccan palm groves and to upgrade this sector through introducing bayoud resistant varieties, management development of date palm cultivation techniques and marketing of products.

Cross-sectional programs

Cross-sectional programs indirectly related to natural resources management and conservation are the PAGER, the PERG, the PNCRR, and the SPP. These programs aim at making up for the slippage recorded by

Morocco since independence regarding the crucial human development indicators.

The Program for grouped supply of drinking water to rural populations (PAGER) was launched in 1995. The PAGER aims at securing water supply of 80% of rural households within a 10–year time frame. It plans to connect to the water delivery system 31.000 villages, hosting 11 million inhabitants. Since 1995, 2,7 million inhabitants scattered over 4.450 villages were able to get water through the PAGER.

The global plan for rural electrification (PERG). The plan aims at supplying energy to 80% of rural households, representing 1.500.000 homes by the year 2010. This plan, initially expected to be completed by 2010 has been so successful that its objectives will be reached four years earlier than planned, around 2006.

The national program for rural roads construction (PNCRR) was initiated following a diagnosis of the rural roads network. Thus, the road department identified 13.330 km that needed core interventions, but the PNCRR concluded that 11.236 km needed emergency action. This plan includes construction of 5.149 km of paved roads and rehabilitation of 6.087 km of earth roads over seven to nine year's period. This corresponds to an average construction pace of 1.200 km yearly.

The social priority program (SPP) targets a group of provinces considered among the poorest of the poor. This program is made up of two major components: education and health delivery services. Following implementation of this program, reported schooling indicators show significant progress in education but still far from narrowing the gaps, which these provinces have recorded, compared to the national mainstream level. As far as health delivery system is concerned, the SPP program performances show the scope of the efforts to be deployed to cover the whole territory with medical health care centers. The same problem holds for widespread dissemination of vaccination coverage in these provinces. Therefore, these performances remain far from matching populations' needs.

CURRENT PLANS AND PROGRAMS FOR DESERTIFICATION CONTROL AND NAP PROJECTS

The solutions suggested to control natural resources degradation, often inspired by government services, did not lead to the expected results. Incoherencies and constraints identified can be grouped into six main categories: the legal and organizational frameworks, programs scope and procedures for their design and implementation, staffing and funding mechanisms.

The National Action Plan (NAP) came at the right time to pave the way for success conditions of desertification control programs. Actions have been amply covered by numerous plans analyzed previously. For these reasons, the NAP is not duplicating the existing plans and programs, but it is rather complementing them by bridging their gaps, or catalyzing their implementation through removing the hurdles standing in their ways and through supportive facilitating actions or any others allowing to deepen knowledge of the environment and improving the decision support tools.

The NAP is not the only planning framework in Morocco; rather, it fits into a broader national framework, integrating the whole set of activities and initiatives linked to sustainable development. These different frameworks overlap and do have relations, which need to be fine-tuned and put in a coherent form in order to attain the crucial synergy and complementarity for creating favorable conditions to the sustainable development of the country.

Actions for mitigating desertification

Village-based forestry and windbreaks

The NAP projects to revitalize the spirit of the 1976 Law on population participation in the development of the forestry economy and to act in synergy with the provisions of the Reforestation Master Plan (PDR) through promoting tree planting in consultation with the villagers through their representatives in their elected councils. Setting up the armature areas will be coordinated jointly with the forestry departments, which will provide tree plant material and technical expertise, while the NGOs and the communes will be responsible for sensitizing the populations, also for carrying out the plantation process.

Development of forest and peri-forest pilot zones

Implementation of the reforestation master plan cannot yield satisfactory results in the absence of an integrated development dynamic involving forests and peri-forests areas likely to relieve the current pressure exerted on the forest. In this regard, 10 forest and peri-forest areas have been targeted to serve as integrated development projects monitored by forestry development centers specifically assigned for this task.

Incentives for creating and organizing farm lease hunting rights

Sport hunting is a recreational activity, which has grown considerably in Morocco in recent years. In addition to its positive impact on the conservation of animal and plant biodiversity and on the development of ecotourism, a type of hunting, which is organized and regulated, could prove to be rich in terms of job opportunities.

Promotion of rainwater harvesting

The scarcity of water in arid areas impedes seriously the welfare of the rural populations. Although this scarcity is slightly alleviated, in the case of drinking water owing to the PAGER, it nonetheless remains acute in some areas inflicted as usual by deficits in rainfall, such as in the Anti Atlas, part of the central Meseta and in the PreRif. Implementation of projects to harvest water resources will prioritize indigenous approaches particularly, the local programs will harvest rainwater through retention dams or other forms of reservoirs offering real possibilities to compensate, even partially, for the water deficit, which is becoming acute in Morocco.

Consolidation of agricultural, forestry and rangeland sustainable development

The major concern of restoring population trust in government actions justifies the option adopted by the NAP to support the action plans and programs underway, which meet the most immediate needs of the populations and which mainly concern basic infrastructures and improvement of the living conditions (upgrade basic infrastructures, earth roads and watering points).

Energy program and sustainable development

The energy and sustainable development program seeks to give substance to the numerous isolated actions conducted by the NGOs in various places in the country. Implementation of this program will be effected in close collaboration with the Center for the Development of Renewable Energies and the local associations. It will also pursue the main objectives of promoting rational management of wood energy and encourage the use of alternative sources.

Wood and its charcoal byproduct represent 39% of total energy consumption in Morocco. It constitutes the main source of energy in the rural world and covers almost 80% of the energy needs. The problem of fuel wood is not posed in the same manner all over the territory, and specific needs are expressed in each of the mountain, plain, city and steppe areas. They relate mainly to heating water, improvement of traditional baths, energy efficiency, cost effectiveness of public ovens, and affordability of gas cylinders and promotion of photovoltaic kits (AGR/DAF, 1999).

Strengthening of baseline knowledge and development of natural resources monitoring systems

Inventory of soil and vegetation resources

Morocco has recorded important slippages in establishing the inventory of its renewable resources. As a matter of fact, outside the irrigated area, the cartography of soil resources is still incomplete. It is also the case for the floristic resources, whose inventory at the national level is available only at 1/2.000.000 scale. The NAP projects contribute to gather human resources within the Ministry of Agriculture and the State Secretary in Charge of Water and Forestry in order to overcome this constraint. At the same time, the use spatial remote sensing techniques will allow the completion of this work under advantageous cost and duration conditions.

Setting up of a drought and desertification control observatory

Drought is currently considered as a structural problem of Moroccan climate. Its management should therefore be planned through a long-term vision because its impacts on rural populations are so severe and long standing that it cannot be overcome through targeted programs or hasty and short-lived emergency measures. The struggle against drought effects should rather fit the framework of a voluntary-based strategy, whose operational arm is a functional early warning system. The latter's main prescriptions should be articulated around water harvesting, efficient use and savings of this scarce commodity.

It is in this context that a National Drought Observatory (ONS) has been created recently. It is given the mission to monitor and evaluate ecological, economic and social impacts of the drought. The observatory will serve as a clearinghouse for monitoring and supervision of programs for the Fight against desertification (LCD). It should promote concertation between all development agencies concerned with drought consequences. It should also contribute to the design of an early warning system allowing delivery of drought relief services at the right time and under adequate conditions. Adoption of objective criteria for specification of the degree of severity of the drought in the various areas of the country will ease the identification process of distressed areas and the most vulnerable population groups, who should receive priority state relief actions.

The observatory will establish links with structures already operating in natural resources monitoring. It will function in the form of a network, grouping a central unit and regional rollovers interacting with all the partners involved in monitoring and mitigation of drought effects, including the NAP's implementation. The central unit of the observatory will be assigned the tasks of ensuring coordination, orientation and implementation of its respective activities (Ameziane et Ouassou, 2001).

Strengthening the network for ecological monitoring

Desertification control should primarily rely on short and long term monitoring facilities with a view to achieving the following: (i) to better understand the mechanisms leading to desertification, (ii) to establish sound criteria allowing an accurate specification of desertification causes and effects, and (iii) to identify the methods and techniques likely to promote natural resources conservation and the protection of the environment.

The network of observatories for long term ecological monitoring (ROSELT) developed by the Observatory for Sahara and Sahel (OSS) has been designed as the operational framework for such a facility. Taking into account the diversity of the ecosystems of our country, ROSELT has labeled 3 out of 11 potential areas, namely Issougui, Fezouata and Oued Mird.

Monitoring and evaluating the impacts of desertification control programs

This activity will serve to provide relevant information allowing assessment of the program performances in order to make suitable amendments to the LCD programs. The designed system will, then, be validated through chosen sites, representing the severest forms of desertification in Morocco and in which desertification control programs are either implemented or underway.

In the first place, the project will cover four pilot sites located in: (i) the Oriental for rangeland management, (ii) Rif-Chefchaouen for forestry management, (iii) Tadla plain for groundwater rise and (iv) ROSELT site in Ouarzazate for a dynamic monitoring of the pre-Saharan ecosystem. Effective implementation of the system, to cover the whole of the identified ecosystems of the territory in 12 sites by 2020, will follow initial operations of the project and is scheduled over a 2-year period.

The NAP’s impact monitoring and evaluating system

Monitoring the impacts of the NAP’s actions on natural resources should be an on-going task. It plays the role of an instrument panel at the disposal of the National Coordination Body (NCB) to whom it provides relevant and timely information necessary to make decisions regarding continuation of programs or their adjustment as needed.

One of the priorities identified in these programmes is the diffusion of information among different stakeholders and the public.

The information medium of the monitoring evaluation function will be entrusted with the Desertification Information Traffic System (SCID). The SCID covers theme desertification of the Environment Information and Data System (SIDE). The SCID is a monitoring and evaluation system and a support tool for decision making, which will make information available to the NCB and to other NAP's stakeholders. It appears in the Web site of the Ministry of Agriculture.

Programme SID-SISEI (Système de circulation de l'Information sur la Désertification-Système d'Information et de Suivi de l'Environnemental sur Internet) aims to set up an Internet based network devoted to the improvement of the diffusion of information. The project sets up a Moroccan Internet portal linked with a network of a Clearing House Mechanism (CHM) at country level. The creation of the network of CHM increases the accessibility to information and at the same time the creation of national meta-data base will improve the achievement of the better accessibility. The use of intern*et al*lows to share existing knowledge on the issue of desertification.

PRINCIPAL CONCERNS IN THE FIGHT AGAINST DESERTIFICATION

In water resource mobilization, the country has at present 100 large and medium dams of a total storage capacity of about 14,3 billions of m³ used at the level of 80 % by the agriculture (Ait Kadi, 2002).

In agriculture development, approximately one million hectares located mainly in dry and semi-arid zones are at present irrigated of which 671.000 hectares are in large parcels. For the rainfall agriculture, a new strategy that integrates local participation is in preparation (Ait Kadi, 2002).

The pastoral development program allowed the identification of 19 locations of pastoral improvement and the constitution of 42 cooperatives and groupings in the various pastoral zones. Actions concern sowing and planting of the rangeland areas by herbaceous pastoral species or shrubs and fallowing the natural vegetation in pastoral perimeters.

For the forested sector, realizations concerned the demarcation of approximately 4.165.000 hectares of forests and 300.000 hectares of stipa area, the resource inventory of 2.446.000 hectares, the forest management of 1.065.000 hectares and 2.300.000 of the stipa area and the reforestation of 530.000 hectares. The erosion measures and soil conservation concern more than 530.000 hectares of which 31.000 hectares of sand dune stabilization (AEFCS, 1996; AGR/DAF, 2002).

Three national parks Toubkal, Tazeka and Souss-Massa, covering a surface of 83.000 hectares have been created and are in the process of management, in order to preserve and protect native fauna and flora. Two reserves for Argan and Palm plantations were also created.

Actions taken in the fight against the desertification include i) the mobilization of 14.3 billions of m^3 of surface water, ii) the irrigation of one million ha, iii) the reforestation of 530.000 ha, and iv) the actions for water and soil conservation on 530.000 Ha. of which 31.000 Ha. is for sand control (AGR/DAF, 2002).

In addition, a special program for the attenuation of drought effects was executed during 1999/2000 (Table 1) and 2000/2001 campaigns with the objectives of job creation, livestock protection, drinking water supply, forest protection, the cereal market supply and the treatment of farmers debts. This program which mobilized a budget of 7.5 billion dirhams, offered the opportunity of a real test in the field of the integration, the coordination and the decentralization (Ameziane et Ouassou, 2000).

Table 1. The 1999/2000 program for drought mitigation

	Cost	
Operations	**Amount** (Millions of Dh)	**%**
▪ Job creation	4.323	54.0
▪ Livestock protection	1.339	16.7
▪ Drinking water supply	676	08.4
▪ Forest protection	288	03.6
▪ Cereal market seed supply	180	02.2
▪ Treatment of farmers debts	1.200	15.0
▪ Communication	4	0
Total	8.010	100

The interest shown by Morocco regarding desertification control and drought effects mitigation is appraised through the initiatives taken to create optimal conditions for implementing sustainable development programs, natural resources conservation and preservation and retrofitting programs to enhance infrastructure and basic social services.

The effort extended by the state can also be appraised through the importance of the funds raised during the 5-year development program underway (2000-2004) in order to implement programs and development actions in connection with desertification control and poverty alleviation. The budg*et al*lowance stands at 17.7 billion dirhams (Agriculture and Water and Forestry sectors).

DESERTIFICATION CONTROL IN THE 2000-2004 SOCIO-ECONOMIC PROGRAM

The main programs, linked to desertification control and drought alleviation and for which necessary funding has been raised for the 2000-2004 five-year plan, are the following AGR/DAF, 2001):

-*Management of irrigated lands*: The program for the management of irrigated lands brings to bear on the following: (i) expanding irrigation over an area of 86.120 Ha. in large scale hydraulics and 13.620 Ha. in the small-sized hydraulics, (ii) rehabilitate irrigation in an area covering 14.400 Ha. in large scale hydraulics and 136.500 Ha. in small and medium-sized hydraulics.

-*Management of rainfed agricultural lands*: This program concerns the following: (i) rock picking 40.000 Ha. on agricultural lands, (ii) rehabilitation and clearance of 16.,000 Ha. of agricultural lands, (iii) land consolidation of 98.000 Ha. and (iv) establishing partnership schemes with growers for erosion control on 16.000 Ha. of cropped lands.

-*Management of grazing lands*: Several operations are programmed, among which the dynamic monitoring of vegetation in 7 sites, fallow on 450.000 Ha. of rangelands, plantation of fodder shrubs on 16.500 ha, soil tillage and seeding of 26.000 Ha.

-*Reclamation of rainfed lands*: The program is made up of 70 local projects for rural and agricultural development, extending over 1 million Ha. to benefit 120.000 growers (women and men).

-*Management and forestry development programs*: The programs encompass management of 14.700 Ha. of forests, the reforestation of 114.000 Ha., erosion control in six watersheds, sand dune stabilization of 1.800 Ha. and biodiversity management of 21 identified sites.

-*Programs for yield and quality improvements of agricultural products*: They mainly concern: (i) expanding olive plantations over 150.000 ha, (ii) renewal of citrus plantations on 34.000 ha, (iii) genetic improvements of goats, sheep and cattle, and (iv) numerous other actions and experiments involving various aspects of agricultural production.

-*Training, research and outreach programs*: Several actions are planned under this topic, the most important of which are strengthening and spreading vocational and technical training in the field of natural resources conservation, management, production of a 5 million Ha. land vocation map, upgrading and promotion of dry farming techniques.

CONCLUSION

Desertification in Morocco involves a mixture of unfavourable natural conditions in combination with social, political, economic and cultural factors that affect negatively and often irreversibly most land and mainly marginal land. Its has negative consequences that affect the quality of life of the population and lead to poverty and an increase in unemployment, which are the main cause of migration to urban areas or even neighbering countries.

This presents a new security challenge for the Mediterranean countries. It is important to recognise and cope with the outcomes of potentially violent societal consequences and to develop cooperation and dialogue between countries from each side of the Mediterranean Sea. Those problems could be alleviated by the participation of the northern countries in the socio-economic development projects of the southern countries. The southern countries, in turn, could develop an agreement with the northern countries to regulate the flux of migration and to cope with the security problem.

In this sense, Morocco has made desertification control and drought mitigation its top priority in its socio-economic development programs. Since 1996, through surveys and workshops several priority programs have been identified and have been implemented to alleviate poverty and maintain rural populations.

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DESERTIFICATION, TERRITORY AND PEOPLE, A HOLISTIC APPROACH IN THE PORTUGUESE CONTEXT

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ABSTRACT

The paper discusses some basic concepts relative to desertification processes that support a more holistic approach to the problems faced in the country. A concept where land is seen as a territory and where land and water resources combine with human resources and opportunities for development is assumed. The identification of areas susceptible to desertification is described and the insufficiency of used indicators is discussed, mainly in relation to the climatic driving forces including droughts. Observations referring to vulnerability indicators show that the desertification processes affect large areas or territories where water resources are scarce, soil resources are often poor and non-agricultural vegetation is far from climax. Furthermore, natural resources seem do not respond anymore to the demand of the modern society particularly concerning agriculture. Thus, former equilibriums in land use and land condition are broken or tend to be disrupted while the population in these areas shows less capability to reverse the present situation. In areas susceptible to desertification, population density is very low and the respective growth rate is highly negative, aging is increasing with the dependency on aged people, illiteracy is above average, and the purchasing power of population is much lower than average. A desertification cycle and issues to reverse the situation are discussed. These include the need for the society to understand that policies to combat desertification shall focus the populations with priority over the environment in order to re-establish or create new equilibriums. The need for public participation, innovation on local political functioning, regionalization, development of public awareness, and education are also discussed.

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INTRODUCTION

The concept of desertification is associated with land degradation, water scarcity and, for some, mainly with soil erosion and loss of productivity due to human causes and climatic change in arid to sub-humid climates. However, despite the definition produced by the UNCCD (UNCED, 1992) is generally not questioned, there is not a common agreement in its interpretation or about the concepts behind it.

Numerous papers were produced about desertification in the Mediterranean context presenting a vast panoply of approaches and concepts (e.g. Coelho, 1999; Balabanis *et al*., 1999; Enne *et al*., 2000; Geeson *et al*. 2002). Many papers in these volumes use a limited approach to desertification and to land degradation because they refer to focused research, thus generally looking only a part of the land degradation problem and related responses. Often, the concept of land is replaced by that of soil, as in many desertification studies relative to water erosion, or to a canopy, like in research on vegetation vulnerability. Nevertheless, there is a trend to better integrate the different factors that characterize the land, as it is the case of studies relative to data, indicators and measures to prevent or to combat desertification (e.g. Enne and Zucca, 2000; Enne *et al*., 2000 and 2001; SlNCID, 2002; Briassoulis *et al*., 2003). However, the water factor is generally not enough considered.

More integrative approaches, where the concept of land approaches that of landscape and, as proposed by the UNCCD, includes soil and local water resources, land surface and vegetation or crops (UNCED, 1992), are more often present when national perspectives are discussed (e.g. Roxo and Mourão, 1998; Martin de Santa Olalla, 2001). The social and economic context favoring or being affected by desertification also has more relevance when national perspectives are considered. This situation identifies a possible gap between research studies and national identification of vulnerable areas and response measures. Research focuses on the processes with great detail, mainly the physical ones, while approaches to identification of problems and related issues in a national perspective tend to produce a holistic view at the spatial scale. Similarly, the concept of (land) degradation as proposed by the UNCCD (UNCED, 1992), i.e., the reduction of the resource potential by one or a combination of processes acting on the land, is generally focused on one process only in research papers but viewed in a wider perspective when a larger spatial scale is used.

The water resources factor is often minor or not considered at all when land or land degradation are treated in desertification studies. However it may play a determinant role because the water resources at local scales establish a link between climatic driving forces and land conditions (adopting for land the concept of complex system comprising soil, water, and vegetation). On the one hand, the climatic conditions determine the amount, time and spatial variability of precipitation and, indirectly, the regime and quantity of evapotranspiration (ET) from natural and man-made ecosystems. Therefore, the precipitation and ET regimes influence and characterize land conditions. On the other hand, the land condition, referring to soil hydraulic properties and vegetation cover, influences or determines the partition of the precipitation into the various components of the hydrologic cycle, i.e., interception, direct evaporation, surface runoff, and infiltrated water, which partitions again into vegetation ET, subsurface flows and groundwater flows. Therefore, water resources influence and are affected by land condition, mainly in which concerns the hydrologic balance at the local scale. The man influences on the hydrologic cycle and balance may then favor water scarcity at both local and basin scales. Difficulties in treating the problem are evident, thus most common approaches are made at a large scale, relative to water resource management (WMO, 1996, Pereira, 2001, Pereira *et al.,* 2002).

These differences in approaches and the difficulty in assuming the UNCCD definition in an operational way, that considers the integrative aspects of the factors and processes affecting desertification, may lead to reduce the full understanding of desertification and, consequently, the vulnerability of the land or the territory to desertification. That is why, in Portugal, a wider approach is adopted by considering that desertification not only affects the soil and water resources but also the territory with consequences on all activities, not just agriculture. In other words, desertification impacts on the urban, rural and agricultural societies living in relatively vast territories where the degradation of natural resources and the pressure on the use of land and water is creating adverse conditions for the people living in such environments.

In fact, public opinion commonly associates the term desertification to loss of population, lack of opportunities for development, and lack of jobs for the younger generation. In developed countries, such as those of northern Mediterranean that are part of Annex IV of the UNCCD, the consequences of desertification in terms of reducing the capability of land to produce food are less significant because they add to impacts of the

Common Agricultural Policy - mainly relative to reducing agricultural land - and are difficult to be distinguished from the later. However, changes in land use that produce a decrease in agricultural activities have enormous impacts in less favored regions. Migration from these regions to urban areas leads to land abandonment and policies favoring a decrease of agricultural intensification favor emigration and aging of populations. A wider concept of land approaching that of territory is therefore assumed in this paper, which is in agreement with the large, global scale approach often advocated in other studies (e.g. Reynolds and Stafford Smith, 2002).

Nowadays, in large areas, the population is not anymore sufficient to keep a demographic balance and to maintain social and economic activities at a minimum standard level, including schools, health services and markets of essential goods. Great forest fires occurred this year of 2003 throughout the country, mainly where the degradation of the territory, including that of the living conditions of the people is more acute. Land abandonment and forestation of traditional agricultural areas near to small rural towns have created conditions to increase fire propagation and to endanger populations. Desertification became therefore a question of security: the regions that are a continuous source of immigration have nowadays problems similar to those faced centuries ago when the territory was recently conquered, with a lack of population to assure the occupation and the life of the territory. The consequences of such a situation are yet not known.

This paper views desertification as a large-scale land and territory degradation, and assumes a holistic perspective to all driving factors and consequences of desertification, including those relative to the populations and related security issues.

CONCEPTS

The UNCCD (UNCED, 1992) defines desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Land includes soil and local water resources, land surface and vegetation or crops, while degradation implies reduction of the resource potential by one or a combination of processes acting on the land. However, as discussed above, these definitions need to be broadened in scope to also focus attention on the water scarcity issues and the consequences for the populations living in affected areas.

The term desertification was formerly used to define a man-made water scarcity regime (Yevjevich *et al.*, 1983) aiming at making it clear the distinction between natural and man-made xeric regimes, and among their time scales (Table 1).

Table 1. Xeric regimes and respective time scales

Xeric regimes	**Nature produced**	**Man induced**
Permanent	***Aridity***	***Desertification***
Temporary	***Drought***	***Water shortage***

Along this line, the definitions reported in Table 2 were recently adopted in view of water resources management in water scarce areas (Pereira *et al.*, 2002).

Table 2. Definition of the xeric regimes

Aridity a nature produced permanent imbalance in the water availability consisting of low average annual precipitation, with high spatial and temporal variability, resulting in overall low moisture and low carrying capacity of the ecosystems.	***Desertification*** a man-induced permanent imbalance in the availability of water, which is combined with damaged soil, inappropriate land use, mining of groundwater, increased flash flooding, loss of riparian ecosystems and a deterioration of the carrying capacity of the ecosystems.
Drought a nature produced but temporary imbalance of water availability, consisting of a persistent lower-than-average precipitation, of uncertain frequency, duration and severity, of unpredictable or less-predictable occurrence, resulting in diminished water resources availability, and reduced carrying capacity of the ecosystems.	***Water shortage*** a man-induced but temporary water imbalance which may result from general excessive exploitation of available resources and degraded water quality which exacerbates the effects of water scarcity.

The aridity as a xeric regime is the immediate result of the climate. Desertification is considered to occur where the climate produces water scarcity regimes and fragile ecosystems, with low carrying capacity. Drought, which is a natural consequence of climate variability, aggravates the water resources insufficiencies as much as they are influenced by aridity, particularly at the local level, reduces the carrying capacity of the ecosystems, affects injuriously the plant and animal life of a place, and contributes to deplete water supplies for domestic purposes and other uses. Drought increases the land vulnerability to desertification in addition to other factors that cause land degradation.

Water shortage is a man-induced temporary water imbalance resulting from excessive exploitation of available resources, for example when withdrawals exceed groundwater recharge, surface reservoirs are inadequately managed, and land use has changed, so modifying the local ecosystems and altering the infiltration and runoff characteristics. Degraded water quality aggravates those water imbalances. It is important to recognize that water scarcity results from human activity, either by over-use of the natural supply or by degradation of the water quality. Water shortage may contribute to desertification mainly when appropriate measures are not taken to solve the respective causes. This man-induced water scarcity is common in semi-arid and sub-humid regions where population and economic forces may produce large pressure on the local water resource, and where insufficient care is taken to protect the quality of the resource. Therefore, water shortage may be considered as a first or inductive stage of desertification (Pereira *et al*., 2002), while drought strongly aggravates the process of desertification when increasing the pressure on the diminished surface and groundwater resources, in particular when aridity conditions prevail (Figure 1).

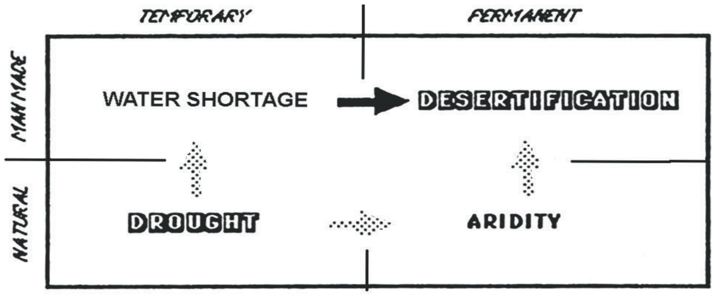

Figure 1. Man-made water shortage as a trigger factor of desertification as influenced by drought and aridity (modified from Correia, 1999)

From the previous discussion, it seems more appropriate to define desertification in relation to water imbalance produced by the misuse of water and land resources, so calling attention to the fact that misusing water definitely is a cause of desertification.

The concept of climatic variations needs to be clarified. Droughts, which are a consequence of climatic variability, do not cause desertification but aggravate land vulnerability when the causing processes are forcing land degradation. Instead, climate change may impact desertification by creating uncertainties in water supply and demand.

The consequences of land degradation need also to be broadened in scope since local populations are affected and the respective social and economic behaviour change. Moreover, the capabilities of populations for reacting to the negative impact of desertification are reduced, both increasing the vulnerability to the processes and diminishing the capabilities to reverse them. As pointed out before, the public opinion in Portugal commonly associates the term desertification with imbalances in the opportunities for development which may have large economic and social consequences.

When the National Action Program to Combat Desertification was established, among 79 actions proposed by stakeholders and the population only 5 related to the agricultural soil; all other were relative to living conditions of people, economic activities including the non-agricultural ones, and water, i.e. the term land was largely assumed as territory.

The scheme in Figure 2 describes that broadening of concepts, making clear that land degradation is a reduction in the soil, water, vegetation, and land and water use potential as influenced by the climate and the climate change, which impacts the economic activities of the territory affected and the societal conditions of the populations.

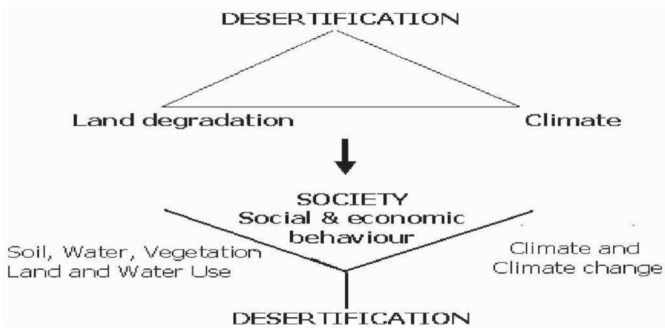

Figure 2. Expanding the scope of desertification

Without promoting a different definition, desertification is therefore considered as a man-induced long-term imbalance in the use of the land, the availability of water, and the opportunities for development, which affects the territory and the populations in arid, semi-arid and sub-humid climates, and combines damaged soil and degraded vegetation, inappropriate land use, mining and degradation of groundwater, increased flash flooding, and a deterioration of the carrying capacity of the ecosystems. Drought and climate change strongly aggravate the process of desertification when increasing the pressure on the limited natural resources. Soil erosion and salinity and forest fires are often contributing to the desertification process.

VULNERABILITY TO DESERTIFICATION

Climate and Water

Susceptibility to desertification is assessed using large sets of physical, social and economic indicators. However, related analyses are also being performed (Rosário, 2003).

Climate influences are considered through the aridity index I_A, ratio between the annual averages of rainfall and ET (ETo). Maps relative to annual average values of both variables (1961-90 for ETo and 1960/61-90/91 for rainfall) are presented in Figure 3.

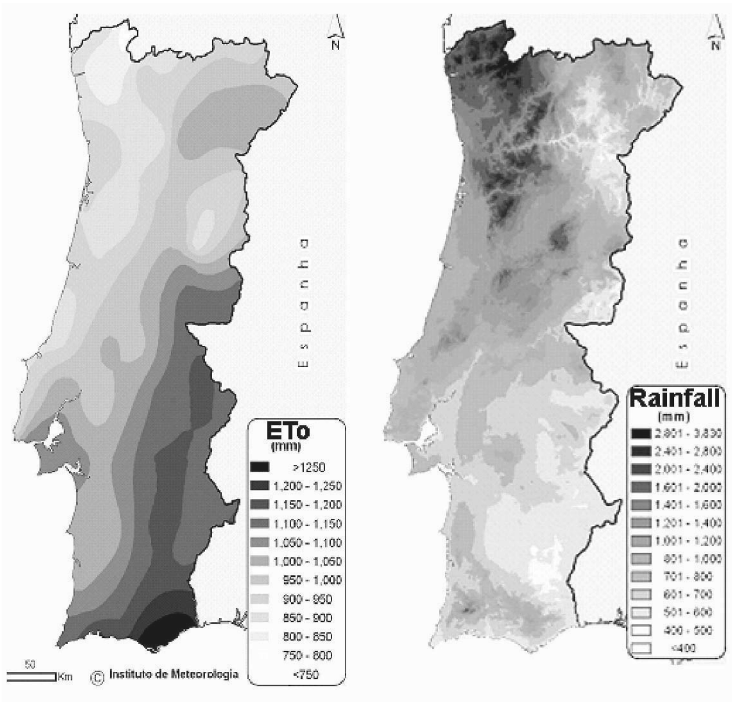

Figure 3. Average annual evapotranspiration (ETo) and rainfall
(Source: Institute of Meteorology)

The maps in Figure 3 show that the annual ET increases from North to South and from the coast to inland, ranging between <750 mm and >1250 mm, while rainfall is much higher in the Northwest, where it may exceed 3000 mm, and lower in Southeast, with minimal values <450 mm. Rainfall distribution is tied to elevation and the general circulation of the atmosphere. The resulting map of the aridity index I_A expresses a similar spatial pattern (Figure 4), with the semiarid and dry sub-humid areas occurring in the South and East of the country.

The annual runoff varies from <200 mm in the South to > 2000 mm in the Northwest (Figure 5). The annual runoff may be assumed as a rough indicator for water resources availability because groundwater resources are relatively scarce and are correlated with runoff (INAG, 2001). Its spatial distribution (Figure 5) shows a pattern essentially depending on the rainfall but generally compatible with that of the aridity index (Figure 3) which indicates that the water scarcity concept of aridity and climate aridity are also compatible. However, a water scarcity index was not computed since it applies to large areas only (Pereira *et al*., 2002). The analysis performed noticed that the climatic aridity index is sensitive to the length of the periods of calculation and to the ET equation used, e.g. the Penman *vs*. the FAO Penman-Monteith equation (Allen *et al*., 1998), which therefore calls for an interdisciplinary effort of standardization.

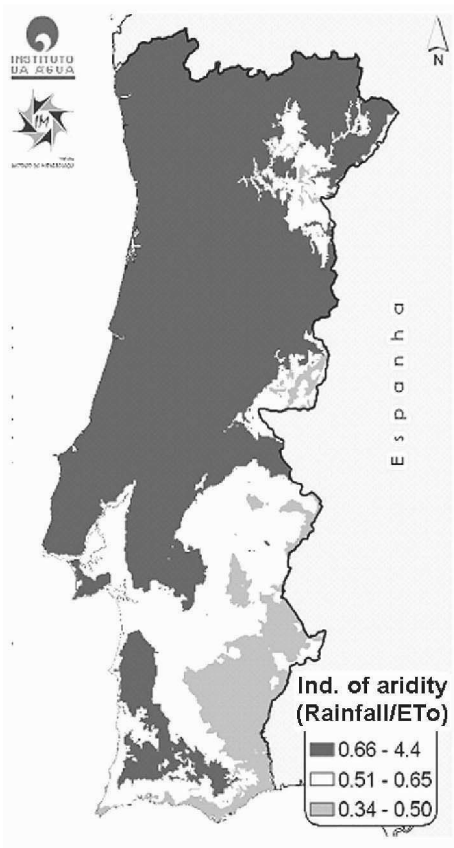

Figure 4. Rainfall to ETo ratio as climatic aridity index I_A
(Source: Institute of Meteorology and Institute of Water)

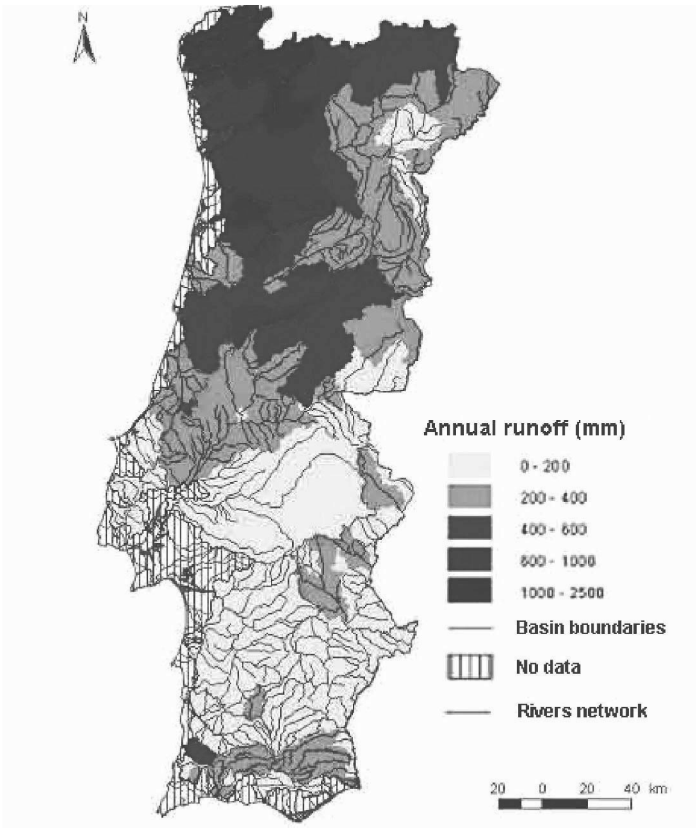

Figure 5. Average annual runoff (source: INAG, 2001)

It was observed that the southern part of the country, the Alentejo region in particular, which is the area with less rainfall and less runoff or water availability, is a drought prone area. Several studies have characterized the local and regional droughts in Alentejo, e.g. Santos (1983) and Henriques and Santos (1996). Recent research using the standardized precipitation index SPI (Paulo and Pereira, 2002; Paulo *et al*., 2003a) characterize the frequency, duration and severity of droughts. Meanwhile, probabilistic tools for prediction of drought class transitions are being developed, which may help both to combat droughts and to contribute for controlling the drought induced vulnerability to desertification (Paulo *et al*., 2003b). Using the SPI, it could be confirmed that droughts in the region affect a large percentage of the area of the region, are relatively long, averaging near 2 years, and are often severe or extremely severe, with severe droughts generally affecting near 100% of the region (Figure 6).

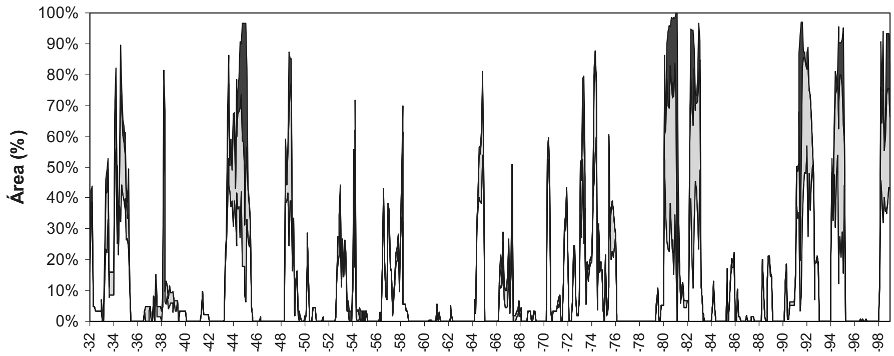

Figure 6. Area percentage of Alentejo region affected by droughts during 1932 to 1999: moderate ☐, severe ☐ and extreme ☐. Droughts (Source: Pereira and Paulo, 2004)

When considering the single aridity index I_A computed from average rainfall and ET values (Figure 4) droughts are not considered because they result from climate variability processes, which are not possible to be expressed through average computations. Because droughts are part of the climate driving forces influencing desertification, the usual aridity index maps are not fully appropriate to be used as a climate base to map the areas susceptible to desertification. Moreover, such a climate index should also be an indicator of water resources availability, which is impacted by droughts. Observing the spatial variation of the aridity index in the region (Figure 4) and knowing that the occurrence of severe droughts affects the entire southern Portugal, it seems appropriate to revise the computation of the aridity index I_A aiming at adopting a climate base map that considers the influence of droughts. One alternative now under consideration is computing the I_A index using selected probability values for rainfall and ET that may express a climate trend instead of using simple mean values in such a way that those areas commonly affected by severe droughts are included in the climate susceptible areas. Studies for validating this procedure are being performed.

Physical Factors

The soil susceptibility indicator is a combined index resulting from the consideration of soil thickness, saturated hydraulic conductivity or infiltration, structural stability of aggregates or resistance to erosion, presence of stones, drainage and salinity problems, and land slope. Efforts need to be made to change from an indicator calculated from some soil characteristics, mainly relative to soil degradation, to an indicator that better expresses land capability and adequateness of use, including when soil and water conservation measures and structures are adopted. It is desirable that such an indicator has the capability to express the dynamics of land use when a surveillance system would be operational.

The vegetation indicator is a complex index which takes into consideration the risk to fire, the resistance of vegetation to water stress, the canopy characteristics relative to protect the soil against rainfall impacts that produce soil detachment, the characteristics of the canopy cover, and the proximity of actual vegetation stands of the climax vegetation. As for the soil index, there is the need to improve the vegetation indicator in order to make it easily responsive to changes in vegetation.

A land use quality index completes the set of adopted physical indicators. It is also a composite index resulting from the consideration of non-agricultural uses – urban, industrial and tourist uses -, wetlands, and irrigated areas. Again, it is required to improve this index to consider other land use characteristics that give indication of the economic and social benefits related to land use, as well as about the dynamics of land use change. An index representing landscape feature may be considered. Adopting remote sensing information to revise the existing indicators and to define new ones is under consideration. Meanwhile, as a result of consideration of indices referred above, a map of susceptibility to desertification is shown in Figure 7. It reflects the present state of knowledge and therefore it is just a basis for further work to better identify the vulnerable areas.

This map is not entirely compatible with that of forest fires that occurred during 2003. These fires had a distribution pattern different from the past ones (Pereira and Santos, 2003) because they covered large areas where land abandonment and reforestation of traditional agricultural lands are dominant and population is now very scarce. Therefore, despite the socio-economic factors were not yet used in mapping the susceptibility to desertification, the approach utilized is generally coherent relative to those factors. However, a great effort is required to adapt maps to reality, particularly for the areas identified only in relation to the soil factor and relative to the aridity index, which insufficiencies are analyzed above. A new multi-institutional and multidisciplinary approach is being developed to identify indicators, namely through the European project DIS/MED (Rosário, 2003).

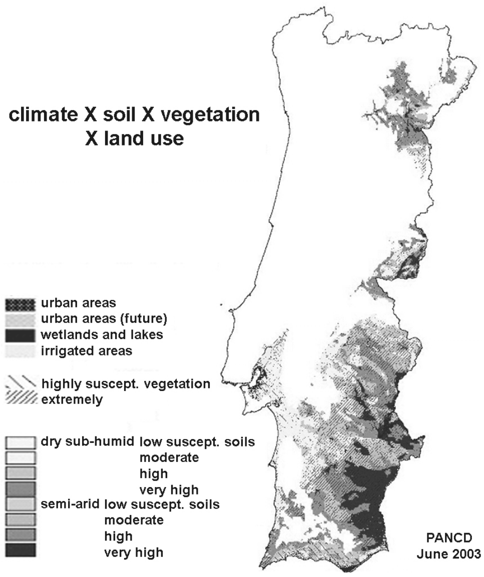

Figure 7. Susceptibility to desertification resulting from combining climate and physical factors

Socio Economic Factors

In pilot areas, the stakeholders and the population identified desertification referring first to the economic factors that determine the living conditions of the population, and in second place the aspects relative to the loss of population in these areas. The physical aspects such as those relative to soil erosion, water scarcity, degradation of the vegetation cover, and land abandonment appear only after the socio-economic ones.

This perception of desertification by the local populations gives great relevance to the socio-economic factors as driving forces of desertification and as indicators of vulnerability. In fact, low opportunities for employment in agriculture or in non-agricultural activities are a cause for the loss of population due to migration to urban centers and abroad in search of new opportunities. This causes the disruption of the rural world and certainly increases the vulnerability of land to desertification in quite vast territories.

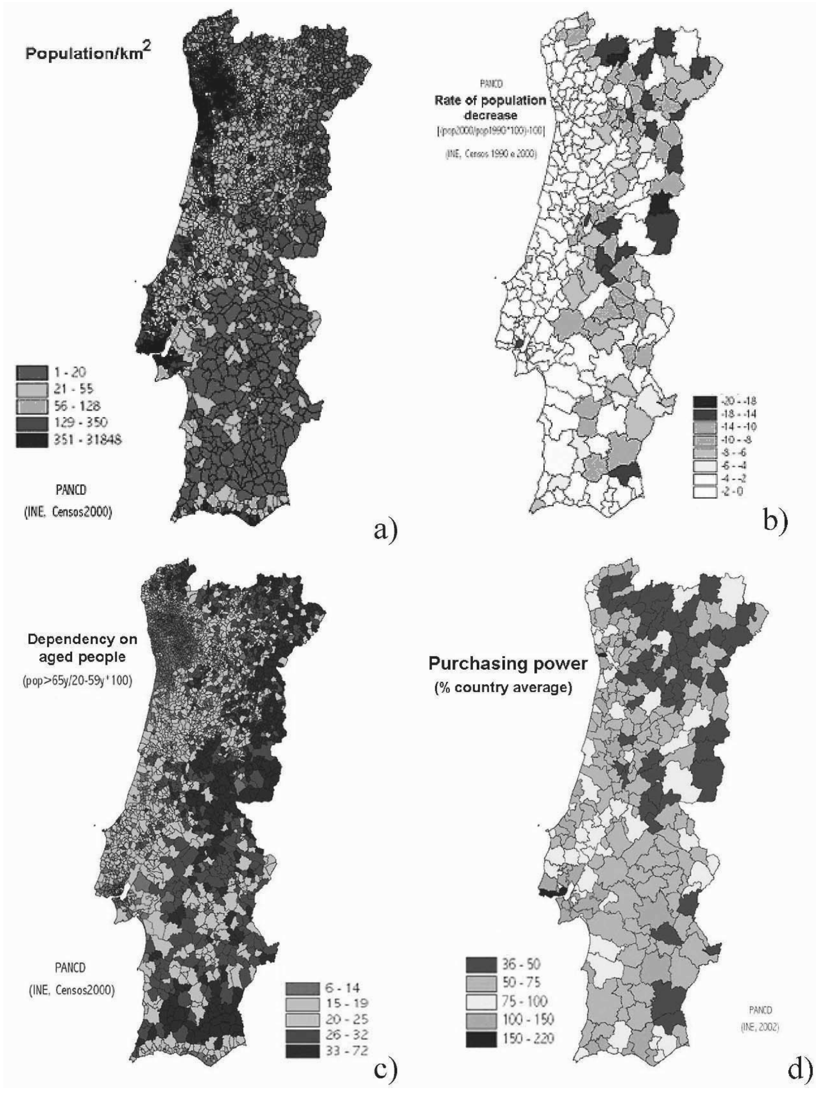

Figure 8. Socio-economic indices relative to the year 2000: Population density, rate of population decrease, dependency on aged population and purchasing power (Source: National Institute of Statistics)

It can be observed (Figure 8a) that the southern and inland parts of the country have the lowest density of population, with < 25 inhabitants/km^2 in most of areas identified in Figure 7 as more vulnerable to desertification. This low density highly contrasts with the coastal areas, mainly those near centers of industrial and tertiary activities, where that density is at least four times higher. This means that desertification is associated with depopulation. Probably due to this aspect, the most depopulated areas are those where, excluding the tourist attraction areas, the percentage of secondary houses is higher (data not shown), i.e. these largely correspond to houses of migrant population.

In addition to low population, those inland areas where vulnerability to desertification is higher are also among those where the population decreased for the last decade (Figure 8b), which indicates migration to other areas in the country or abroad. This depopulation is associated with a strong aging of the resident population, which creates a heavy dependency of all activities on aged people (Figure 8c). This dependency index (%) is defined by the ratio between the population aged above 65 years and the population aged from 20 to 59 years. Inland and southern areas show index values above 25%, with large areas having an index > 33%, which coincide with the most vulnerable ones. In addition, the worst values for the illiteracy index (not shown) occur in the same areas where population is more aged and the negative growth rate is higher.These low levels of population, their decrease and aging do not favor opportunities for development which could reverse those negative trends. Therefore, in areas where resource are poor or limited, the populations face the lowest living standards as indicated by the purchasing power index (Figure 8d). This index is a complex combination of several economic and living standard indices that compares living conditions in each municipality with the national average (100). Once more, the lower values occur inland and in the southern areas, coinciding with the more vulnerable regions of the country.

ISSUES FOR PREVENTING AND COMBATING DESERTIFICATION

The identification of areas susceptible to desertification as described above considered the climate and physical factors but not yet the socio-economic ones. Moreover, the climate base map, resulting from the average rainfall to ETo ratio, is insufficient to consider in full the climatic driving forces that influence the desertification process, mainly droughts. However, it was possible to map the areas susceptible to desertification by combining that climatic index with other indices relative to soil, particularly referring to erosion risks, fertility, infiltration, and drainage conditions; to vegetation, including the risk to fire; and to land use. The resulting map reveals coherence when considering the potential availability of water resources represented through the spatial pattern of precipitation and annual runoff. However, the water resources availability at the local level was not assessed.

Observations referring to the vulnerability indicators referred above show that the desertification processes interest large areas or territories where water resources are scarce, soil resources are often poor and non-agricultural vegetation is far from climax. Furthermore, natural resources seem to do not respond anymore to the demand of the modern society particularly in that concerns agriculture and the Common Agricultural Policy. Thus, former equilibriums in land use and land condition are broken or tend to be disrupted while the society in this areas has not been able to find new equilibriums, showing low capability to reverse the present socio-economic and environmental situation.

This is particularly evident when analyzing the socio-economic indicators as shown above. In areas identified as susceptible to desertification population density is low to very low and the respective growth rate is highly negative. Aging is increasing as well as the dependency on aged people for every activity at local level. Housing is at a low level but secondary houses constitute a high percentage indicating migration of population to more attractive locations. Illiteracy is above average. The purchasing power of population is much lower than average, so indicating a progressive impoverishment. A question arises: are these population characteristics a cause or a consequence of a desertification process?

The fact is that these negative socio-economic conditions in the vulnerable areas are related with the poor land resources, mainly soil and water, less adequacy of ecosystems to support development, low response capacity to climate forcing, and non existence of alternative activities to agriculture and forestry. When external economic forces act over such fragile systems they tend to collapse, i.e., the existing equilibriums brake easily. Conditions are created for the climate forcing to exacerbate the vulnerability to desertification, mainly when scarce water resources do not allow improved land use. This cycle is represented in Figure 9.

More than control and mitigation measures, preventive measures are required to avoid that desertification install where fragile equilibrium are broken. Re-establishing or finding new equilibriums in the use of natural resources are required but the priority is probably to be assigned to improve living conditions of the population. Without population, with human deserts, there is no way to solve desertification problems. The priority on measures relative to human resources in depressed areas is a question of security.

In developed countries such as those of northern Mediterranean that are part of Annex IV of CCD, the consequences of desertification in terms of reducing the capability of land to produce food are not significant. The Common Agricultural Policy is also not oriented to production. The issue is to keep those rural landscapes alive, developing new uses for the natural local resources that are compatible with the economic living of populations, the conservation of resources, and the leisure use by the growing urban world. Therefore, policies have to be found that stop or, better, reverse emigration and aging of populations. Because in large areas the remaining population is not anymore sufficient to keep a demographic balance and to maintain social and economic activities at a minimum standard level, including schools, health services and market of essential goods, the solution of the problem cannot be found with the local people alone but as a matter of interest for the society.

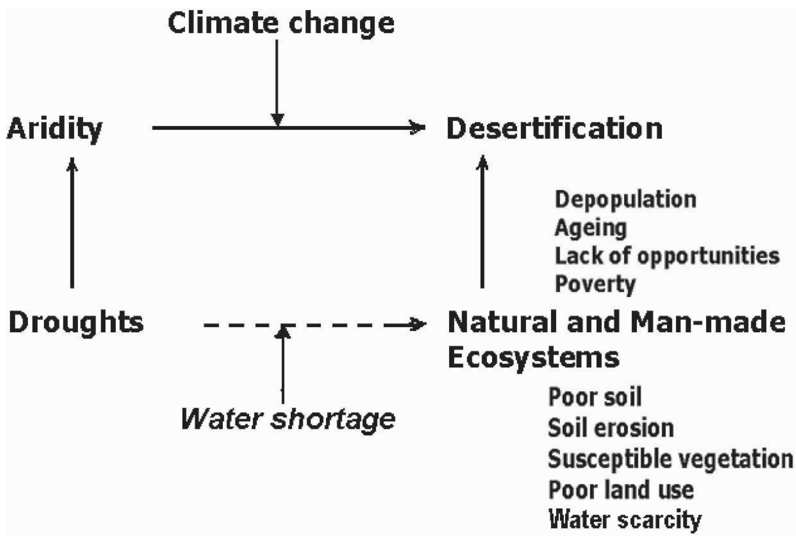

Figure 9. The desertification cycle as influenced by climate, land resources, man land and water use, and human resources

Great forest fires occurred throughout the country during the summer 2003. This was an occasion for the public to be concerned but the understanding that these fires occurred dominantly where the degradation of the territory and of the living conditions of the people are more severe was not carried by the media. In fact, the conditions that favored land abandonment and the forestation of the traditional agricultural areas where such fires developed were not discussed or considered in order to prevent future calamities that mainly affect and endanger the local depressed populations.

Preventing and controlling the processes of desertification is also a question of security. In the vulnerable areas there is a continuous source of immigration that produces nowadays problems similar to those faced centuries ago when the territory was recently conquered: there is a lack of population to assure the occupation of the territory. Because of this depopulation, many basic services are not provided and there is no economic justification for keeping such services. Thus, instead of attractive conditions, repulsive ones are passively created without proper evaluation of the consequences of such a situation.

There are a variety of measures but their implementation requires not only technologies and funding but also the involvement of the society and the public at all levels. In degraded regions prone to desertification, the response of populations to any incentive is limited. This fact creates increased difficulties to develop and implement measures that could fight both the causes and the consequences of desertification. New approaches to the problem are required, particularly relative to policies of regional and rural development. Policies to combat desertification are matters involving innovative economic and social measures in addition to those relative to environment. It is the people and the territory that must be the target of such policies, not the soil or the vegetation.

Public participation is a key factor. It relates also to innovative political issues concerning the local governance and to decentralization.

Public participation calls for information. With this objective, the National Action Program to Combat Desertification (PANCD) as created a website allowing to consult maps and metadata associated with a map. But this is only a part of the information required because it shall interest a vast public and the media.

A great effort must be placed on increasing the public awareness on the natural resources and on the depressed lands and territories. The general public is becoming aware of environmental problems but not yet about measures and practices that lead to the preservation and conservation of man-made resources and landscapes, mainly of measures that may contribute to the solidarity with populations living in depressed areas prone to desertification. The largest effort must probably be placed on education, not only the children and youth, but the society and those responsible for decision-making at all levels.

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MIGRATION: AN IRREVERSIBLE IMPACT OF LAND DEGRADATION IN TURKEY

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ABSTRACT

The total arable land in Turkey is 28.054.000 ha. However, the prime soils cover only 17.5% of the total land surface and the productivity of the remaining soils is mainly limited by topography, depleted organic matter and high clay contents.

The long standing deforestation, unsuitable tillage and irrigation management have induced the rate of erosion since historical periods. The majority of the country's soil (76.5%) are prone to erosion risk due to the dominant steep slopes (>6%), and 72% of the soils are more or less affected from water and wind erosion (CCD-Turkey, 2003). Soil sealing and extraction of raw material together with overuse of fertilizers and irrigation have led to the improper use of traditional environmental friendly agroscape (agroecosystem), thus constantly degrading the soils of the country. Secondary salinity builds up in the primary saline zones as well as the fertile alluvial planes of Turkey, which are actually the gene zones of many crops particularly cereals, legumes and halophytes, pointing out to the reality that irrigation management plans should not only be based on the concept of conventional cash crop production but also for the crop present on the indigenous agroescapes. This necessitates the incorporation of the halophyte production in the central Anatolian steppes and the olive/carod/vine production in the semi-arid Mediterranean karstic region together with the south east Anatolians calcrete agroscapes. This paradigm is sustainable land use management aims to increase the welfare of the urban people and decrease the threat of excess water use in fragile steppe, karstic and calcrete topographies, which are also the carbon pools of the world. Hence, the concept of agroscapes based on landuse assessment should primarily be considered in the development of sustainable land management strategies particularly with the incorporation of indigenous environmental friendly technical knowledge to combat land degradation and desertification.

The high population increase in the urban regions and conversely the decrease in the rural, cause the intensive use of arable land around the former inducing desertification. According to the census of 2000, 40%of the country's population live in rural area (23.797.653 out of the total 67.803.927) with an average of 1.21 ha/man arable land, mostly allocated for cereal production (country average ~2000Kg/ha.). This is equivalent to a low

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net income rate, which results to migration from the rural areas to urban, particularly from the east of the country to the west. The Government Statistics Institute (2003)date reveals that from 1990 to 2000, the urban population increased by 30%, ie from 33.656.275 to 44.006.274, whereas the rural increased at much lower rate (4.3%). This data reveals the pressure of both natural and human induced factors on soils and land urgently in need of sustainable land management policies along the legislations, since, the rate of quality loss of land and soil, ie desertification in the coming decades will ultimately be the common jeopardy in the country.

INTRODUCTION

The major impact of land degradation in Turkey is erosion and soil sealing, which have been the outcomes of population pressure mainly induced by migration and population increase. Migration has shown trends with the developing industry bound to the shifts in political/economical paradigms beginning in the mid-1950s.

The high population increase in the urban regions and conversely the decrease in the rural, cause the intensive use of arable land around the former inducing desertification in Turkey. According to the population census of 2000, 40% of the country's population lives in rural areas (23.797.653 out of the total 67.803.927) with an average of 1.21ha/man arable land, mostly allocated for cereal production (country average ~2000kg/ha). This is equivalent to a low net income rate, which results to migration from the rural areas to the urban, particularly from the east of the country to the west. The State Planning Office (SPO, 2001) data reveals that from 1990 to 2000, the urban population increased by 30%, ie from 33.656.275 to 44.006.274, whereas the rural increased at a much lower rate (4.3%). This data reveals the pressure of both the natural and human induced factors on soils and land urgently in need of sustainable land management policies along with legislations, since, the rate of quality loss of land and soil in the coming decades will ultimately be the common jeopardy in the country.

IMPACTS OF LAND DEGRADATION

Historical Erosion

Bal *et al*. (2003) have demonstrated the impacts of historical erosion occurring along the Mediterranean Coast by an improved method using historical data and Geographical Information Systems (GIS) technology. The development of the deltas at two selected sites on the Turkish Mediterranean coast have been determined to date back to 6000 and 4000 years BP respectively (Figure 1).

Sample sites exhibiting similar development following deposition of transported soil materials can be found throughout the Mediterranean coasts of Southern European and North African countries (Eswaran and Reich, 1997; El-Beltagy, 2000), reshaping the Mediterranean ecosystem to its present condition.

Actual Erosion and Soil Sealing

The Mediterranean Basin has experienced intensive human development as population increases, causing an irreparable impact on its ecosystems, much longer than any other parts of the world since the Neolithic (Kapur *et al*. 1999; El-Beltagy, 2000; Bal *et al*. 2003, Conservation International, 2003). In this context, the biggest impact of human civilization has been deforestation for urban development (soil sealing), and clearing for agricultural land causing severe erosion throughout history. The evergreen woodlands and maquis habitats that dominate the hotspots today are the result of these anthropogenic disturbances over several millennia (Figure 2). Moreover, the unsustainable use of water, supplied from giant reservoirs (the Central Anatolian plateau and the southeastern basins) has induced salinity built up that ultimately resulted in land degradation and desertification.

The actual soil erosion in Turkey is one of the most severe rural and environmental issues affecting 81% of the total land surface in varying levels of severity (Figure 3). About 73% of the cultivated land and 68% of the prime agricultural land -Klingebiel and Montgomery's (1961) Land Capability Classes of I through IV- are prone to erosion.

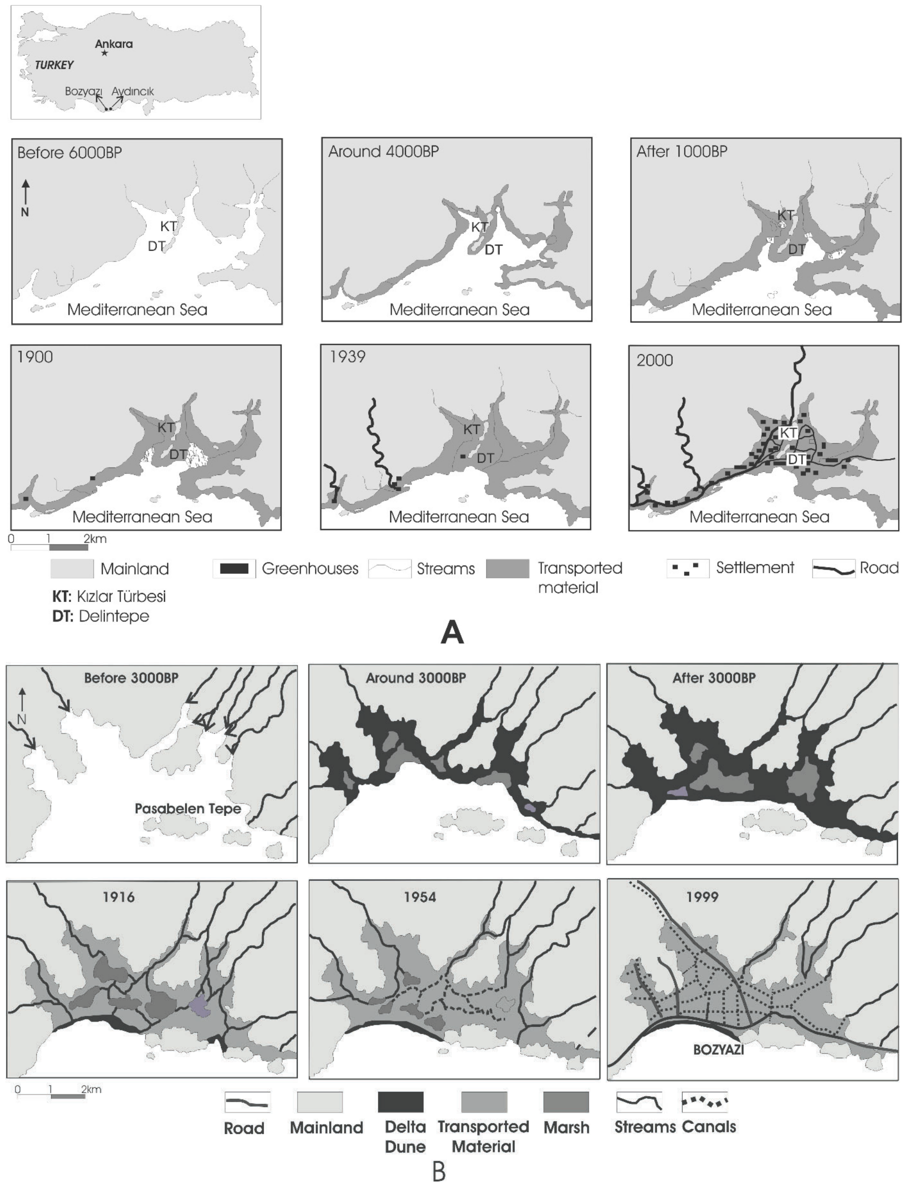

Figure 1. The delta development due to historical erosion in the Mediterranean Coast of Turkey (Bal *et al*. 2003)

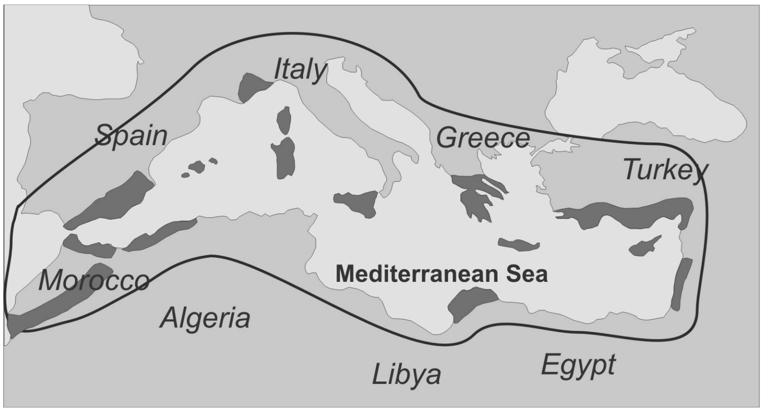

Figure 2. The biodiversity hotspots of the Mediterranean Basin (Conservation International, 2003)

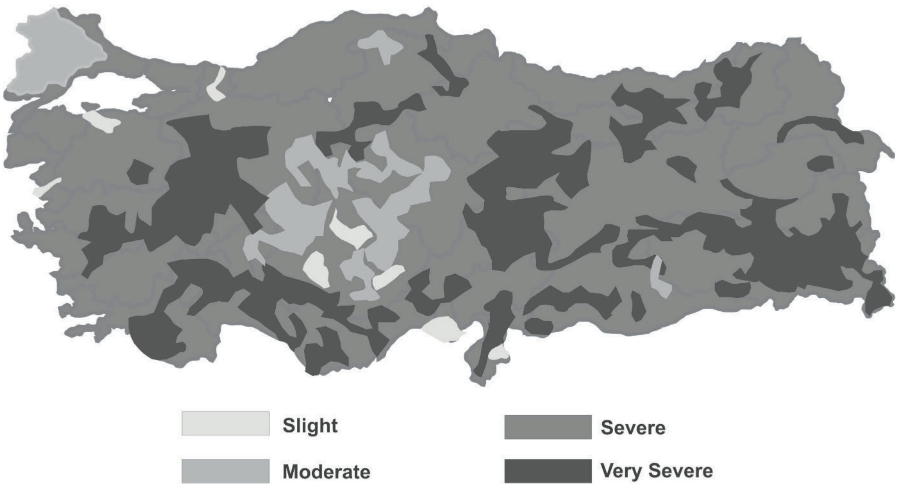

Figure 3. The simplified erosion map of Turkey (modified from GDRS, 1981)

Throughout history, erosion and soil sealing have been inseparable components of the 'causes and consequences' of land degradation and desertification of the Mediterranean anthroscapes[47] (Akca *et al*. 2003), thus the main threats to humanity. Anthroscapes are the lands used for indigenous crops on specific soil surfaces (calcretes of Spain, Turkey and the Middle East and North Africa) with sustainable management of soils as a natural resource since the advent of the pistachio, olive, carob trees and vineyards dating back to 5000 years BP (Dinc *et al*. 2001) (Figure 4). Unfortunately, these anthroscapes are frequently regarded as nonproductive lands due their sloping and undulating topographies overlain by shallow soils. Thus, the will to shift to cash crops, which require high investments such as irrigation, deep tillage along with infra and ultra structures on the calcrete surfaces, induces the degradation of these lands via soil sealing and erosion. Hence, the improper management of these anthroscapes, induced by soil sealing, eventually leads to the decline of the long standing sustainable indigenous productivity obtained from these unique surfaces.

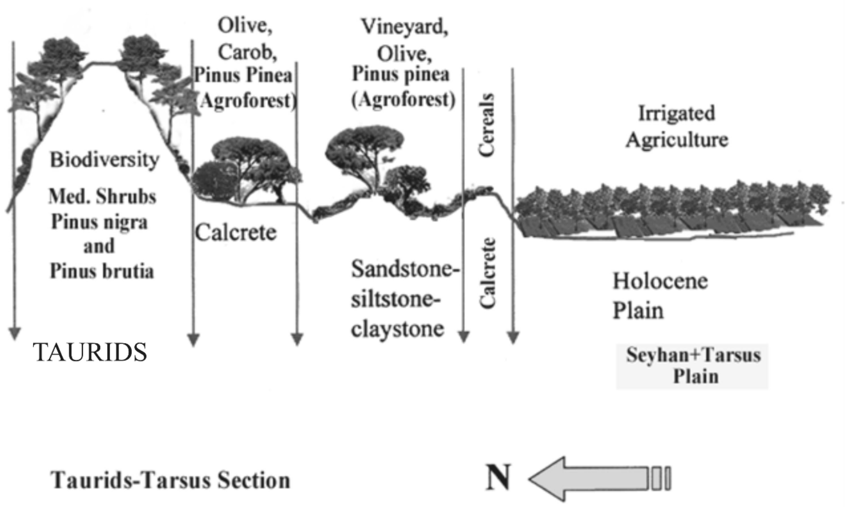

Figure 4. The Taurids-Tarsus Anthroscape Section in South of Turkey

47 The resources management domains of Eswaran et al. (1997), and the surfaces described to developed during the anthropocene (Blum and Eswaran, 2004)

The second concerns the areas subject to soil sealing, related to the expansion of city boundaries, caused by the population pressure which is mainly the consequence of migration and the subsequent increase in population. Since the 1980s an increase in migration has reached dramatically high levels varying from 32% in Bingöl to 45% in Kars which is located in the eastern part of the country (SPO, 2001). This has led to the improper expansion mainly in Istanbul, Kocaeli, Mersin, Antakya, Balikesir, Trabzon, Adana and Gaziantep caused by people seeking jobs in the rapidly developing industry and trade especially in the South and West parts of the country. Thus, the proportion of agricultural land converted for urban purposes follows the trend of migration to the towns mentioned above (Figure 5). Moreover, the mismanaged productive agricultural land increases throughout the country with minor exceptions (Figure 5).

In contrast to the mismanagement of the agricultural lands in the western part of the country which is mainly due to soil sealing, the eastern provinces (eg the Kars, Bingöl and Van) are subject to land abandonment due to migration that leads to discarding the transhumance grazing tradition of that region.

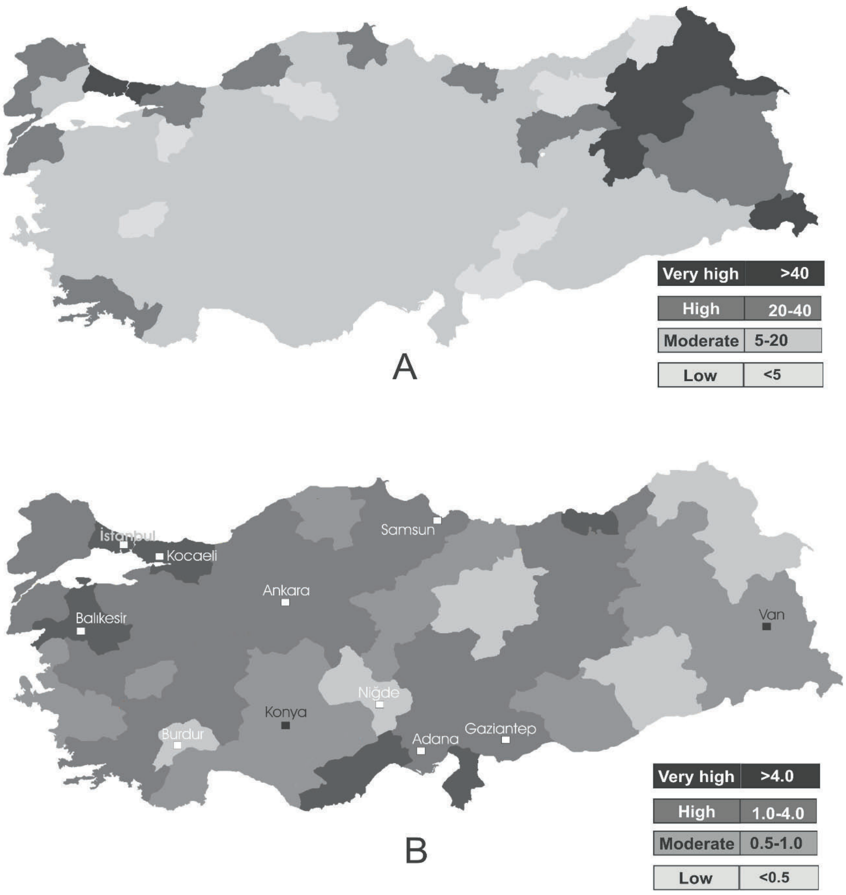

Figure 5. The proportions of agricultural land covered to ourban purposes (A), and agricultural land mismanaged (Cangir *et al*. 2000)

Salinity

Turkey has lavishly been using its rich water resources in the last five decades despite the predicted gradual decrease in precipitation and increase in temperature especially, in the Mediterranean region of the country (Eswaran *et al*, 1998, IPCC, 2001). Thus, numerous irrigation systems have been functioning since the 1950s contributing to the increase of welfare of the rural areas. However, the lack of sustainable land and water management tools led to the development of salinity of prime soils of the country and particularly in some basins of the recently established immense GAP[48] irrigation system which seeks to irrigate 1.7M ha of land, and completed in the near future.

The largest closed basin of the country is the Great Konya Basin of Central Anatolia which is prone to secondary salinity due to its topography. The area is an indigenous land of cereal and fodder production since the Neolithic (Atalay, 2002). However, future irrigation practices, with the use of excess water, within this area, may create drastic consequences due to the existing potential salinity related to high saline water tables (SHW, 2003) of the southern part of the closed Central Anatolian steppe basin. Thus, the indigenous cereal species together with halophyte management in the area should be considered for increasing the welfare of the people.

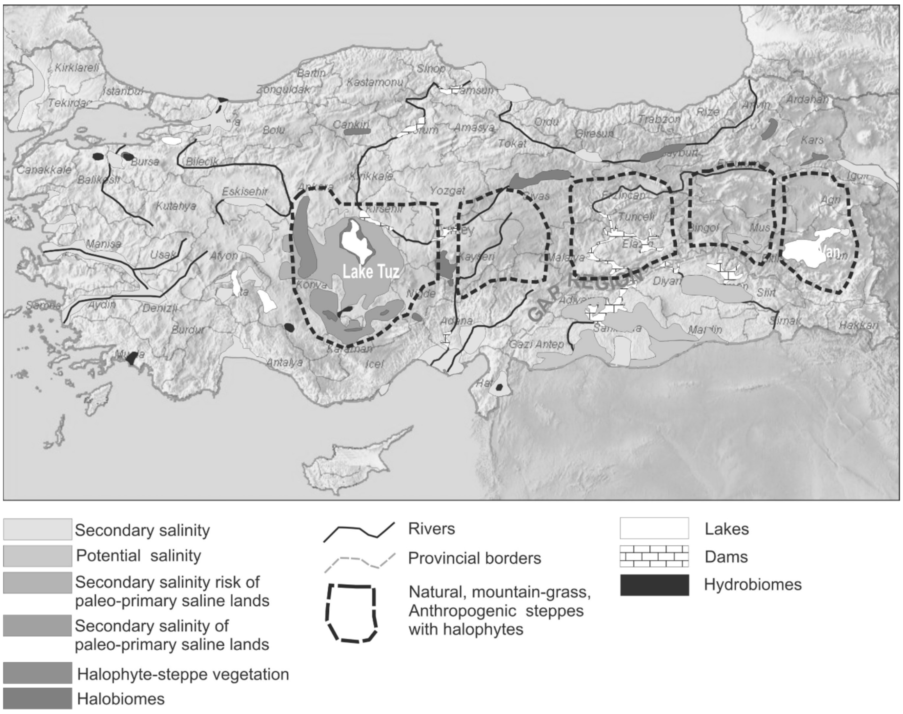

Figure 6. The salinity and halobiome/halophyte map of Turkey (Kapur *et al*. 2003)

[48] Turkish acronym for the Southeast Anatolian Irrigation Project

CONCLUSION

The long standing deforestation, unsuitable tillage and irrigation management have increased the rate of erosion since millennia in Turkey. Soil sealing induced by the recent migration led to the improper use of the traditional environmental friendly anthroscapes, thus constantly degrading the soils of the country. However, the consequences of migration are somewhat constructive in the East by enhancing the natural succession of the degraded vegetation by decreasing the grazing pressure on the traditional grazelands via abandonment.

The demand for higher crop yields due to the population pressure leads to the excess use of water resources and creates salinity in the fertile alluvial plains of Turkey, which are actually the gene zones of many crops particularly cereals, legumes and halophytes. Thus, irrigation management plans should not only be based on the concept of conventional cash crop production but also for the crops present on the indigenous anthroscapes.

The paradigm of sustainable land use management aims to increase the welfare of the urban people and decrease the threat of excess soil and water use in fragile steppe, karstic and calcrete topographies, which are also the carbon pools of the world. Hence, the concept of anthroscape-based land use assessment should primarily be considered in the development of sustainable land management strategies particularly with the incorporation of indigenous environmental friendly technical knowledge.

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PART III

Assessing Land Use Change Relative to Anthropogenic and Natural Cause

DOES ANTHROPOGENIC ACTIVITIES OR NATURE DOMINATE THE SHAPING OF THE LANDSCAPE IN THE OREGON PILOT STUDY AREA FOR 1990-1999?

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ABSTRACT

Climatic variation and human activities are major factors resulting in land degradation in arid and semiarid lands. In the Mediterranean region and over history, climatic drying was coincidental with developing agricultural technology and the rapid increase of the population and their dependence on the grain field, timber, and animal products. As a result of human population demand, it is evident that depletion of natural resources, such as water (surface or ground) and soil (e.g., soil erosion) and reduction of farm productivity, leads many farmers to move to alternative lands or to urban areas. This has a major impact on socioeconomics resulting in a decrease of per-capita food production affecting the political stability of the region and enhancing poverty.

Desertification can be evaluated using environmental degradation. However, it is important to separate degradation that occurred naturally (fire, flood, drought, etc.) or as a result of anthropogenic human activities (urbanization, livestock grazing, etc.). Here we report the use of advanced technology to map changes in vegetation cover that enables managers to geographically locate major changes in loss or gain of vegetation cover. Vegetation cover was assessed over a 10-year period (1990-1999) using 1 km Normalized Difference Vegetation Index (NDVI) data derived from Advanced Very High Resolution Radiometer (AVHRR) biweekly composites. A regression model of NDVI, over time, was developed to identify long-term trends in vegetation cover for each pixel in a study area in the State of Oregon, USA. Since vegetation cover is highly correlated with precipitation, general precipitation trends were also calculated for each precipitation station (n = 73) in the study area. Localized analysis was also performed around precipitation stations, comparing NDVI and rainfall trends in a 3 km x 3 km neighborhood centered on each station. A decreasing trend in vegetation cover was an indicator of some type of stress, either natural (drought, fire) or anthropogenic (excessive grazing, urban growth) in origin. The method

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presented here allows mapping changes in vegetation cover trends over large areas quickly and inexpensively, providing land managers a useful tool in locating areas in most in need of remediation or protection efforts.

Results were mapped using ArcView for visualization and assessments. Three patches of decreasing vegetation cover were identified and analyzed, along with two patches of increasing vegetation cover. Analysis was performed using ancillary data and experts with extensive knowledge of the area. Degradation causes were identified as urban growth and fire. Increased vegetation cover was attributed to recovery in timber harvest areas.

INTRODUCTION

Changes in vegetation cover are related to anthropogenic activity and/or natural causes. In the absence of anthropogenic impacts and extreme natural events (fire, flood, etc.), vegetation cover is related directly to rainfall. Rainfall is one of the most important factors that affect vegetation productivity in a desert ecosystem. In semiarid areas, vegetative cover is related to the amount and timing of rainfall (Lázaro *et al*., 2001). Species composition, abundance, and temporal and spatial distribution of desert annual plants are affected by spatial and temporal distribution of rainfall, seasonal temperature, soil texture, and nutrient levels (Went, 1949; Beatley, 1974; Patten, 1978; Bell *et al*., 1979; Gutierrez & Whitford, 1987; Halvorson & Patten, 1975; Mun & Whitford, 1989, 1990; Nash *et al*., 1999).

Using remotely sensed data, such as the Advanced Very High Resolution Radiometer (AVHRR) to derive the Normalized Difference Vegetation Index (NDVI), is a way to quantify the biomass of actively photosynthesizing vegetation (Eidenshink, 1992). Changes in vegetation cover over time can be used to assess the condition of an area. Restoration of a timber harvest or grazing areas will increase vegetation cover, while adding an impervious surface due to urban growth will decrease vegetation cover. Mapping changes in the vegetation cover using AVHRR is an inexpensive way to monitor and assess changes in environmental condition over large areas.

The relationship between NDVI and vegetation is well documented (Birkey, 2001; Rahman, 2003). NDVI has been used to predict the vineyard leaf area index (Johnson *et al*., 2003), to monitor vegetation response, and to determine the change in vegetation cover over time. Walsh *et al*., (2001) described scale dependence in explaining variation in plant biomass level and concluded that population factors are more important at finer scales and biophysical factors are more important at coarser scales. Species richness of vascular plants and mammals was related to a standard deviation and coefficient of variability of NDVI in Kenya (Oindo and Skidmore, 2002). Hence, habitat heterogeneity that affects species richness can be detected and quantified locally and globally, helping to understand the spatial variability of species richness. In another work, NDVI maps were used to locate urbanization, forest, and other areas (Jones *et al*., 1997).

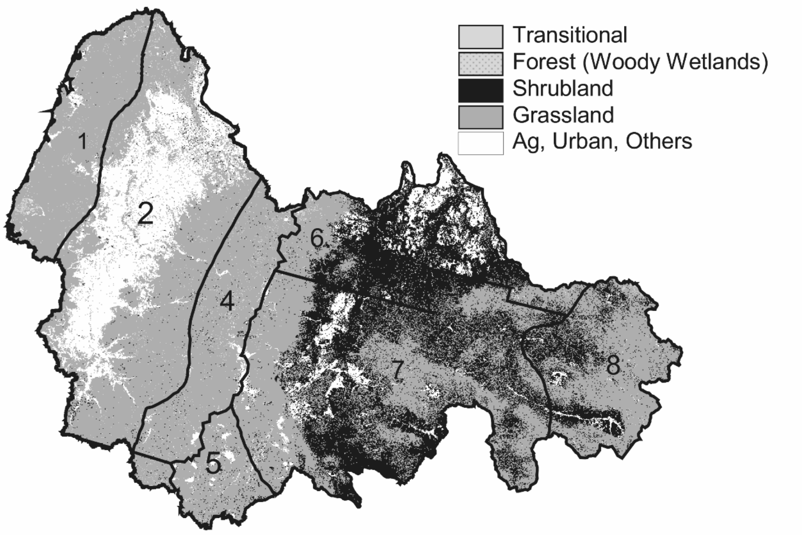
Changes of vegetation were studied to monitor spatial-temporal dynamics of vegetation using NDVI (Minor *et al*., 1999; Lanfredi *et al*., 2003; Gurgel and Ferreira, 2003). Several monitoring studies revealed that a useful relationship between NDVI and vegetation existed during the rainy growing season but not in the dry season (Azzali and Menenti, 2000; Moreau *et al*., 2003). The relationship of NDVI to rainfall in grazing land in Nigeria was of moderate strength during the growing season with rainfall between 250 and 500 mm/yr, but it was weak when the rainfall was below 250 mm/yr (Milich and Weiss, 2000). From a study in northern Australia, Kawabata *et al*., (2001) reported the strength of the relationship ($R^2 = 0.75$) between NDVI and rainfall. Further, they concluded that in arid and semi-arid areas, the rate of plant photosynthesis, as indicated by NDVI, decreased as the rainfall decreased. Similar results were reported by Malo and Nicholson (1990) for the African Sahel region.

Our study area was a portion of the State of Oregon, located in the Pacific Northwest region of the United States (Figure 1). We used time series analyses to quantify changes per pixel. The changes in vegetation cover were determined using the slope value of the regression model of the NDVI ($n = 120$). Our statistical analyses were performed for each pixel over a 10-year period, and results were mapped using ArcView for visualization and assessments for local and regional scales. The objective of the work presented in this paper was to locate areas within the study reach that had a significant change in NDVI readings, and therefore a significant change in vegetation cover.

DATA AND METHODS

Study Area Description

The Oregon study area is one of several pilot study areas included in the United States Environmental Protection Agency (USEPA) Environmental Monitoring and Assessment Program (EMAP) (Jones *et al*., 2000). The size of the pilot area is 80,619 km^2 and covers a gradient of vegetation cover from mountain forest and valley agriculture in the west to dry land dominated by shrubland in the east central and woodland in the far east. Forested upland covered approximately 60 percent of the area (3.34% deciduous forest, 49.31% evergreen forest, and 4.44% mixed forest) and shrubland covered 22.3%. Fourteen percent of the land is agricultural. Land-cover proportions were derived from National Land Cover Data (NLCD) (Vogelmann *et al*., 2001).



Region	n	Dominant Landcover	Annual Precipitation mm/yr Mean	std	Seasonality
1	7	Forest	2261	813	Winter
2	35	Agriculture	1142	310	Winter
4	6	Forest	1559	326	Winter
5	2	Forest	553	198	Winter
6	5	Shrubland	187	25	Winter
7	13	Shrubland/dryland farming	184	66	Spring/Summer
8	5	Forest	236	60	Uniform monthly

Figure 1. National landcover (30 m) for the study area. Annual precipitation for each climate region in the study area for 1990-1999. Rainfall events with more than 6.4 mm were included in this analysis. “n” is the number of rainfall stations per each climate region. “std” is one standard deviation.

Climate data for the State of Oregon spanning the last 100 years indicates cycles of 20-25 years of wet/dry periods. Dry periods were noted in the years from 1920 to 1945 and from 1975 to 1994. A wet cycle appears to have begun in 1994. The years since 1994 have been wet so far. Oregon spans nine climate zones (http://www.ocs.orst.edu/ and click "climate data"); the first is located in the western coastal area, and the eighth and ninth are in the eastern part of the state. The pilot study area includes climate zones 1, 2, 4, and parts of 5, 6, 7, and 8 (Figure 1). The winter months experience the most rainfall, except for zone 8 where the rainfall is uniform throughout the year and in the eastern part of zone 7 where the highest rainfall is in spring and summer.

Aridity increases from west to east across the study area with corresponding changes in dominant landcover and land use activities. Forest dominates along the coast and gives way to shrub-dominated areas toward the east.

DATA

We used biweekly NDVI composites generated from AVHRR data available from the EROS Data Center (EDC; http://geography.usgs.gov/esic/cdrom/usavhrr.html). The composites were compiled by taking the highest NDVI value for each pixel over a 2-week period (EDC, 1999). We only used growing season data, starting in late March/early April and ending in mid-September from 1990-1999. This resulted in a maximum of 12 observations per year and 120 total observations. NDVI data were calculated and scaled to range from zero to 200 (EDC, 1999). Vegetation cover was expected to have NDVI values of 105 or higher (Myneni *et al*., 1997). Prior to analysis, we inspected the NDVI data and found values that were less than 105 or equal to 200. Low values were assumed to be errors or nonvegetated areas and were eliminated. Values of 200 were probably set as a default and therefore were excluded from the data. Another error was an extreme change in value from one date to the next. Groten (1993) developed a method to correct for dust storm and cloud effects on NDVI for a drought study in Burkina Faso. He found that if an NDVI value was less than that of the preceding day by more than 10%, it was due to a dust storm. His algorithm replaced those values by interpolating from prior and subsequent dates. We used his algorithm when consecutive values differed by more than 20. Table 1 shows an example of one and two consecutive dates with errors and the corrected values. When an extreme value was the first or last date in a year, it was averaged with the neighboring observation for the same year only. For example, if the first value for a year was 150, the second was 172, and the third was 174, the first value was considered to be an error. It would be replaced with 161, the average of 150 and 172. NDVI data used for this paper were within an acceptable range (105 < NDVI < 200), and had absolute differences between any consecutive values of less than 20 (see Table 1 for more calculations).

Table 1. Example of NDVI values and calculations

Time	NDVI	NDVI, used	Calculations
1	163	163	
2	139	163.667	$163+\frac{165-163}{3}=163.667$
3	142	164.333	$\frac{163.667+165}{2}=164.333$
4	165	165	
5	158	158	
6	165	165	
7	141	163.5	$\frac{163+164}{2}=163.5$
8	164	164	
9	150	165	

Daily rainfall data from 73 stations for the period of the study (1990-1999) were obtained from the Western Regional Climate Center (WRCC; WRCC, 2002). Depending on the soil moisture and position of landscape, vegetation required a sufficient amount of rainfall in order to initiate and support growth. Whitford (2002) reported a rainfall event of < 0.6 cm may not be sufficient to initiate growth of C_4 grasses and herbaceous vegetation in the Chihuahuan Desert. In a different study, du Plessis (2001) also reported that grasses showed no response when rainfall is # 0.5 cm in arid and semiarid ecosystems. For this study, we considered rainfall events of more than 0.64 cm (0.25 inches) to be the minimum amount of rainfall that could be used effectively by vegetation.

ANALYSES

We quantified changes in vegetation cover using the slope value obtained from a regression model of NDVI over time (n = 120 for complete time series) for each 1 km^2 pixel. We used a time series regression to estimate significant trends in NDVI at the single-pixel level. Time series regression was used because errors in temporal data may be dependent. If dependency exists, then the standard error of the estimate (e.g., slope) will be inflated, and the significant level value of the slope will not be correct. We used SAS for our analyses (proc autoreg; SAS/ETS, 1999). Significance level of the slope was also calculated, using 0.05 as the significance threshold. The significance slopes for the NDVI were mapped for the study area. Positive slopes in NDVI represented a trend of increasing vegetation cover; negative slopes in NDVI represented a decreasing vegetation cover. Eight patches of change were identified and experts with an in-depth knowledge of the area were consulted to determine the cause of change in five of these patches (marked circled areas 1-5 in Figure 5). The utility of Digital Orthophoto Quads (DOQs) and landcover (Interagency Vegetation Mapping Project (IVMP)) were used to explain changes in the NDVI trend in the remaining three patches within the Upper Deschutes (rectangle marked areas in Figure 5).

A localized analysis of NDVI was performed around each rainfall station. The average of NDVI in a 3 x 3 cell window (3 km x 3 km) centered on each rainfall station was calculated for each date, and its temporal trend was quantified using the previously described regression technique (proc autoreg; SAS/ETS, 1999). Trends in rainfall were then compared to vegetation cover (NDVI) trends. In cases of decreasing vegetation cover and increasing rainfall (areas under stress), we mapped the locations and examined high-resolution landcover data (NLCD) to determine a cause.

Since vegetation cover is highly correlated with rainfall, and to identify broad rainfall trends in the study area, overlays of NDVI and rainfall data may exhibit such relationships. The limited number of climate stations did not allow for 1 km^2 scale analyses across the entire study area. However, contours for the rainfall (yearly sum) slopes were generated and overlaid the NDVI-slopes map using GIS.

RESULTS

To observe changes in the level of vegetation cover in the study area over time, the average NDVI for each pixel was mapped for 1- (Figure 2) and 5-year (Figure 3) intervals. A difference map of the two 5-year interval datasets was also generated (Figure 3). A consistent, general increase in vegetation cover over time is clearly visible across much of the area in Figures 2 and 3. This broad trend is corroborated by a general increase in rainfall over a large portion of the area during the same time period (Figure 4), most pronounced in the coastal region (region 1). Local gain in vegetation cover (second five years; Figure 3) in the western part and in the cascades is due to a forestation following Oregon state law in timber harvesting practice. The difference map (Figure 3) shows specific locations where average NDVI increased and decreased from the first half of the study period to the second half. Most of the area experienced small gains (positive differences in average NDVI) in average NDVI. Notable decreases can be seen in the cascades and smaller losses in the Willamette Valley and eastern forests. One patch of a notable increase is a forested area located on the coast. Each of these is also present in Figure 5, discussed below.

The slope of the NDVI over time represented the direction of change in vegetation cover. A negative slope indicated a decrease in vegetation cover, whereas a positive slope indicated an increase in vegetation cover. A portion of the study areas with an increase in vegetation cover was 89% in which only 27% was significantly increased. Moreover, a portion of the study area with a decrease in vegetation cover was 8.8% in which only 0.4% was significantly decreased. Mapping pixels with significant slopes ($p < 0.05$) identified locations where significant changes occurred (Figure 5). Most of the vegetation cover increases occurred in the cascades and in other clusters scattered in the west and east of the pilot study. A decrease in vegetation cover was mainly seen in the Willamette Valley where agriculture is the dominant land use (Figure 5). Loss of vegetation cover was also found in the eastern region in forested and some agricultural areas.

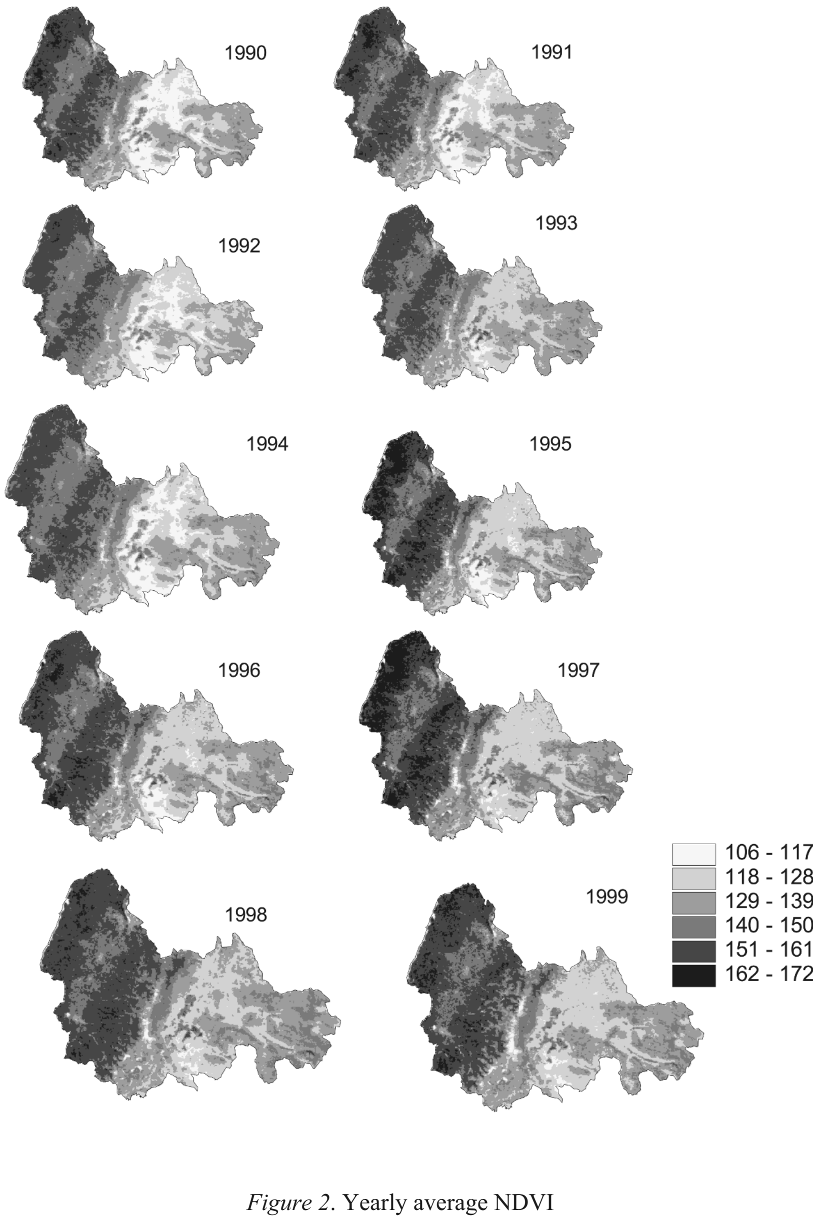


Figure 2. Yearly average NDVI

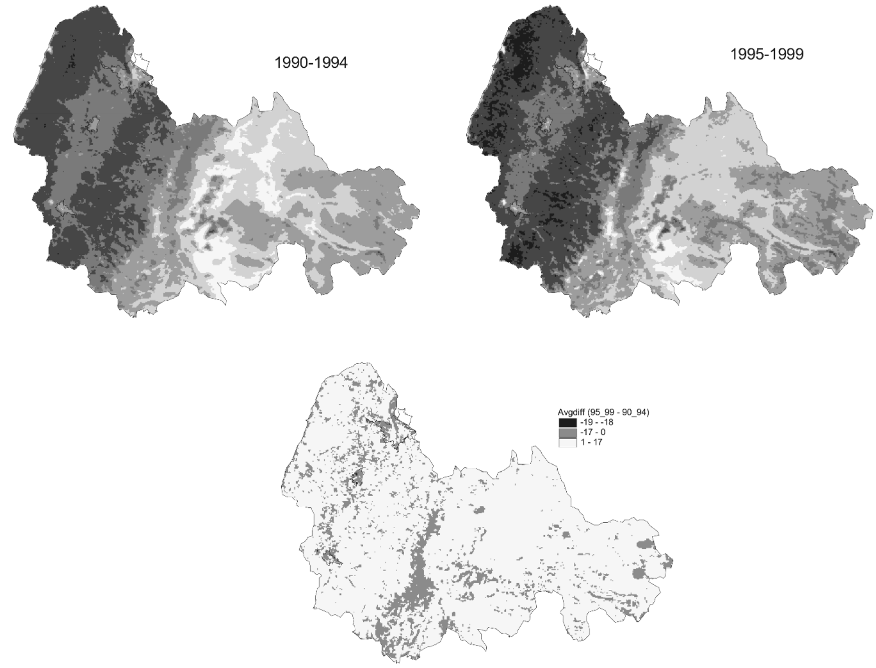


Figure 3. Five-year average NDVI and difference map

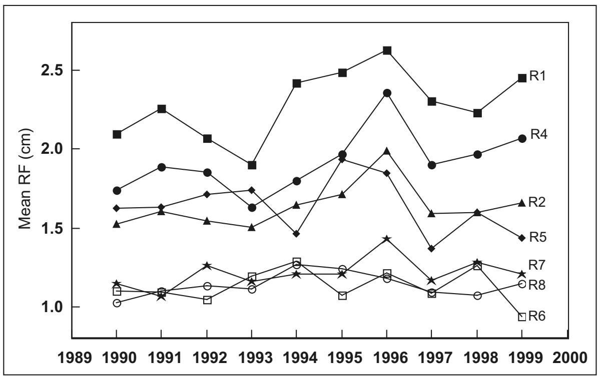


Figure 4. The average amount of rainfall per event per year for each climate region (R) in the study area extended from the west (1; coastal) to the east (8) (see Figure 1 for climate region)

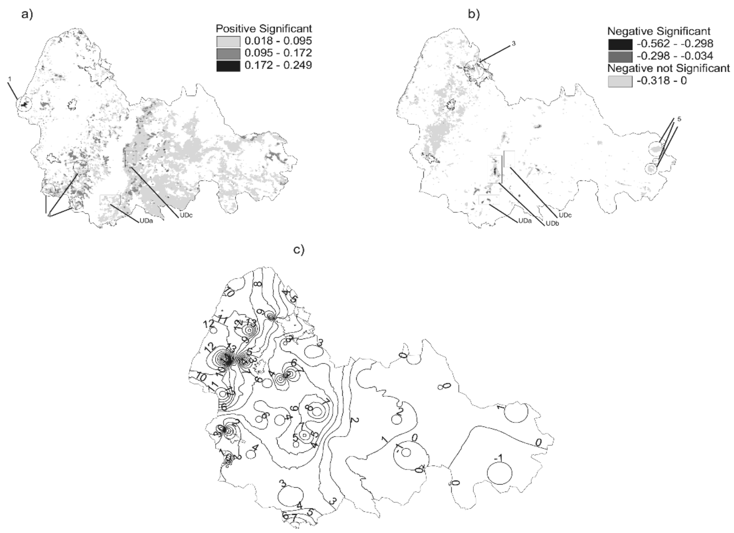


Figure 5. Gain in vegetation cover (a), loss in vegetation cover (b), and contour of rainfall trends (c). Marked areas (1, 2, 3, 4, and 5) are for evaluation using local experts and ancillary data. Polygons on the west side of the study area represent the major urban areas from north to south as Portland, Salem, and Eugene, respectively. Rectangles in marked areas (UDa, UDb, UDc) were examined using DOQ, landcover (IVMP), and the NDVI. UD is Upper Deschutes. Contour lines are the slopes of rainfall (yearly sum) over time

LOCAL ANALYSIS

To identify local areas of interest, the trends in rainfall and NDVI over time for each climate station were compared (Table 2). Of 73 climate stations, seven had a decrease in NDVI and four of these had increasing rainfall, all in the western portion (region 2) of the study area. These four sites were located in urban and agricultural areas. The other three sites had a decrease in NDVI and rainfall, and they were located at an airport (Eugene WSO Airport and Portland WSFO) or on the edge of a lake (O'Dell Lake EAST). It is clear that vegetation cover in these sites decreased due to urban expansion over the study time period.

Table 2. The slope of NDVI and rainfall (RF) over time is indicated by '+' for an increase, '-' for a decrease, and '*' for significant slope (p< 0.05). Slopes are for each rainfall station per region (R)

			Temporal Trend	
R	Station	St_Name	NDVI	RF
1	351682	CloverDale	+	+*
1	352805	Falls City 2	+	+
1	354776	Laurel Mountain	+	+*
1	355971	Nehalem 9 NE	+	+
1	356366	Otis	+	+*
1	358494	Tillamook 1 W	+*	+
1	359372	Willamina	+	+
2	350595	Beaverton 2 SSW	-	+
2	351433	Cascadia State Park	+	-
2	351862	Corvallis State Univ	+	+
2	351877	Corvallis Water Bureau	+	+*
2	351897	Cottage Grove 1 S	+	+
2	351902	Cottage Grove DAM	+	+
2	352112	Dallas 2 NE	+	+
2	352325	Dilley 1 S	-	+*
2	352374	Dorena DAM	+	-
2	352493	Eagle Creek 9 SE	+	+
2	352693	Estacada 2 SE	+	-
2	352709	Eugene WSO Airport	-	-
2	352867	Fern Ridge DAM	+	+
2	352997	Forest Grove	+	+*
2	353047	Foster DAM	+	+
2	353705	Haskins DAM	+	+*
2	353908	Hillsboro	+	+
2	353971	Holley	+	+
2	354606	Lacomb 3 NNE	+	+
2	354811	Leaburg 1 SW	+	+
2	355050	Lookout Point DAM	+	-
2	355384	Mc Minnville	-	+
2	356151	N Willamette Exp Stn	+	+

			Temporal Trend	
2	356334	Oregon City	+	+
2	356749	Portland WB City	+	+
2	356751	Portland WSFO	-	-
2	357127	Rex 1 S	+	+
2	357466	St Helens RFD	+	+
R	Station	St_Name	NDVI	RF
2	357500	Salem WSO Airport	-	+
2	357631	Scotts Mills 8 SE	+	+
2	357809	Silver Creek Falls	+	+
2	357823	Silverton	+	+
2	358095	Stayton	+*	+
2	358884	Vernonia_2	+	+
2	359083	Waterloo	+	+
4	350652	Belknap Springs 8 N	+	+
4	355221	Marion Frks Fish Hatch	+	+*
4	355362	Mc Kenzie Bridge R S	+	+*
4	356213	Oakridge Fish Hatchery	+	+
4	357554	Santiam Junction	+	+*
4	358466	Three Lynx	+	+
5	351546	Chemult 2 N	+*	-
5	356252	O'Dell Lake EAST	-	-
6	350197	Antlope 1 NW	+	+
6	351765	Condon	+	+
6	354411	Kent	+	-
6	355734	Moro	+	+
6	356655	Pine Grove	+*	-
7	350312	Ashwood 2 NE	+*	+
7	35 0501	Barnes Stn	+*	-
7	350694	Bend	+*	+
7	350699	Bend 7 NE	+*	+

			Temporal Trend	
7	352173	Dayville 8 NW	+*	+
7	353038	Fossil	+	+*
7	353542	Grizzly	+*	+
7	355080	Lower Hay Creek	+	+
7	355139	Madras	+	+
7	356243	Mitchell 17 SW Ochoco	+*	+
7	356532	Pelton DAM	+	+
7	357062	Redmond FAA AP	+	+
7	357857	Sisters	+*	+
			Temporal Trend	
R	Station	St_Name	NDVI	RF
8	350356	Austin 3S	+	+
8	354291	John Day	+	-
8	355020	Long Creek	+	-
8	355711	Monument 2	+*	+
8	358726	Ukiah	+	+

REGIONAL ANALYSIS

To ascertain a specific cause of change (grazing, urban growth, fire, etc.) in areas of natural or anthropogenic change, we used local experts and ancillary data. Five areas of interest were identified, three with decreased vegetation cover and two with increased vegetation cover (marked circled areas; Figure 5). The area marked as 1 in Figure 5 is the Siletz watershed in the central coastal area of Oregon (for a report on the Siletz watershed, see Salmon and Forests, http://www.coastrange.org/siletz.htm). This is an area of high intensity timber harvest where 75% of the forest land is owned by private industrial forest companies. This area shows a positive vegetation cover change, possibly due to a forestation and an increase in tree crown diameters, over time. Stocking with healthy tree saplings, or native seedlings, has been required by law in the State of Oregon since 1971. In 1995, a report by the Coastal Landscape Analysis and Modeling Study (CLAMS) (http://www.coastrange.org/siletz.htm) indicated that 65% of the area was covered by 10″ diameter at breast height (DBH) and 18% of the basin lands was covered by conifer or mixed stands (> 20″, in DBH).

The dark black areas within the Willamette Basin, marked as 2 in Figure 5, may reflect vegetation losses due to development. Experts have expressed surprise that there were not more areas of negative change in this area. More extensive significant negative change was expected in the Portland, Oregon, area, marked with a 3 in Figure 5 (personal communication, J.P. Baker). A loss of vegetation cover occurred in the three largest urban areas (Portland, Salem, and Eugene), but not all was significant. The reason is, perhaps, the preservation of partial tree cover in new residential developments and maturation of landscape plantings in existing developments.

The areas marked 4 in Figure 5 include the Cascade Mountain Range where forested areas in the data show a positive vegetation cover change. Perhaps a major recovery in the last decade from heavy timber harvests of the 1980s, the spotted owl rulings, and the North West Forest Plan may have contributed to a decreasing amount of forest harvest (personal communication, G. Bishop).

The patches of negative change, marked as 5 in Figure 5, are the result of two major forest fires that occurred in August 1996 (for date and location of these forest fires west of Baker City, Oregon, see: http://fermi.jhuapl.edu/avhrr/gallery/fire/geo.html#or; and for the Cumulative Fire Spread from 1981-2000, USDA Forest Service Region 4, see: http://www.fs.fed.us/r4/rsgis_fire/images/firehist20yr.jpg). The area of positive change shown between the forest fire areas is the North Fork John Day Wilderness area that was established in 1984. This area has not had any timber harvest since that time, and the change is likely a reflection of increase tree cover.

Three marked areas in the Upper Deschutes (Figure 5; UDa, UDb, UDc) were tested using DOQ and landcover (IVMP). The area marked as "UDb" in Figure 5 is located in the volcanic rock area (dark pixels) of the Oregon cascades. The areas around the lighter pixels were under timber harvesting in the past. DOQ (1994), 1996 landcover (IVMP), and NDVI together showed a positive vegetation cover. The lighter pixels indicate an insignificant decrease in vegetation cover. The signal in NDVI trends may be stronger, and vegetation cover will be higher if more data are included for later years. The area marked "UDc" experienced extensive timber harvesting in the past as indicated by the DOQ and 1996 landcover. Growth of vegetation was enhanced in this area by limiting the timber harvesting and therefore, vegetation cover here indicates the least bare ground and more vegetation growth and cover. The above relationship was not clear in the area marked "UDa". This area is located in a forested lake where the DOQ and IVMP indicate the existence of vegetation cover, yet the NDVI showed loss and gain in vegetation cover pixels within vegetated land and water, respectively. More data will be needed for this site to be verified.

CONCLUSION

We developed a simple method to locate changes in vegetation cover, which can be used to identify areas under stress. The method only requires inexpensive NDVI data, which can be derived from many sources, including basic statistical and mapping software. AVHRR data are useful for evaluating large areas, but finer scale studies can be performed using higher resolution imagery. The use of remotely sensed data is far more cost-effective than field studies and can be performed more quickly.

We also incorporated precipitation data to identify rainfall trends. Local knowledge could be substituted where data was not available, but analysis would be less quantitative. Drought is the most common natural cause of decreased vegetation cover. Areas of decreasing vegetation cover and unchanged or increasing rainfall is likely under stress from a source that can be managed, such as excessive timber harvesting or grazing, urban growth, etc. These areas may represent optimal locations for land managers to take protective or remedial action. In arid and semiarid ecosystems, degradation represented by decreasing vegetation cover may lead to desertification unless action is taken.

For centuries, the Mediterranean land area has been exposed to human impact, particularly through deforestation. Deforestation enhances water erosion and degradation of the physical and chemical properties of soil. Such degradation was quantified in a study in southern Spain. The reduction in the amount of organic matter, cation exchange capacity, and available water content were significant in this degraded soil due to deforestation and if ignored without remediation, desertification is evadable (Martin-Garcia *et al*., 2002). Presently, the causes of deforestation are known and characteristics of degraded soils can be identified, hence, monitoring of changes with the aid of new technology, such as remote sensing and GIS (de Paz and Rubio, 2002), can be established. With experience in the field, all of the above can be implemented to quantify changes and assess conditions of a land. Lessons from the past and appropriate managerial practice tailoring the above knowledge and analyses can be used effectively to maintain the productivity of land that meets the population demand domestically and commercially. The Mediterranean landscape is diverse with different topography, soils, vegetation cover, cultures, and so forth. Our analyses offer results that can be mapped for different scale (locally and regionally) reflecting the diversity in landscape that can be integrated in making the optimum decision in preventing land degradation.

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URBAN GROWTH DYNAMICS (1956-1998) IN MEDITERRANEAN COASTAL REGIONS: THE CASE OF ALICANTE, SPAIN

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ABSTRACT

Among factors causing soil degradation one of the most important, although less studied in Mediterranean environments, is the irreversible loss of soil due to urbanisation processes, inserted into the more general concept of soil sealing. In coastal Mediterranean regions, such as the Valencia Region, Spain, land cover transformations are mainly produced by contemporary socio-economic changes that have produced a drift from traditional agriculture to industrial and tourism economies, reinforced by population's trends to concentrate in cities or larger urban regions. Evaluation of soil sealing is then a key element to understand soil degradation and the disappearance, in most cases, of highly productive soils.

This work, inserted within a major study on land use-cover change and soil degradation of metropolitan areas in the Valencia Region, presents the preliminary results on the urban-non urban (open agrarian and natural spaces) dynamics in the municipality of Alicante, the second largest city in the region. Three sets of panchromatic air photos for the years 1956, 1985 and 1998 have been used. After air photo scanning, on screen digitising using a base digital topographic map at scale 1:10,000, was applied to extract two major types of soil cover: agrarian and urban. A Geographical Information System vector structure has been implemented for cartographic comparison. Finally, to identify spatial and temporal changes maps and overlays together with synthetic tables were produced in order to assess soil degradation.

Results show that there has been a substantial loss of soil devoted mainly to agriculture. Urban growth can be differentiated into three distinct spatial patterns: 1) edge compact enlargement of the city boundaries, including growth following the main road network; 2) compact new urbanisation alongside the coast and 3) the colonisation by groups of individual residences mainly over continental open spaces. One of the main impacts of

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such new urban pattern has been the loss of the most fertile soils distributed over the alluvial plains around the city, which has been mainly occupied by the tourist and residential buildings.

Keywords: Mediterranean environments, Urban dynamics, Desertification, Land degradation, Soil sealing, Aerial photograph, Geographical information Systems.

INTRODUCTION

The expansion of cities has been a relevant feature of the second half of the last century almost in all areas of the planet. Using population concentration as an indicator of urban growth, in 1950 less than 1 billion people, 30 per cent of the population, lived in urban areas; whereas in 2003 the world's urban population was estimated at 3 billion (43 per cent) and is expected to reach 5 billion by 2030, which would be some 61 per cent of the planet's total population (United Nations, 2004).

Although there is a strong relationship between urban population increase and urban expansion, in developed countries the growth of urban areas has to be understood not only by means of population but also as fundamental instruments of modern social and economic trends (globalisation). Such trends concentrate in urban regions labour forces, industrial, commercial and service activities and the required human, physical and technological infrastructures. People grouping in cities are tightly related with modern trends of global economies; although these transforming cities would represent the engines of growth for their respective societies, they are also becoming sources of instability (Van Vliet, 2002).

In some areas, the globalisation phenomenon shows a certain component of social insecurity, because, up to now, the process is basically economical, based on seeking consumers (Environment and Urbanization, 2002), rather than in the setting of equilibrium among resources distribution between consumers and producers and the increase of population's welfare. Instability that is also highlighted by the fact that in the last decades - together with the rapid urban population rise- there has been an even more dramatic increase of urban population with lower incomes (Cohen, 2004).

In such case, urban development becomes a crucial agent in the land use-land cover dynamics of any territory (López *et al.*, 2001; Mendoza and Etter, 2002). The process signifies a radical land use-cover transformation from other uses (normally agriculture or more natural open spaces) that commonly implies the soil degradation (Lambin, 1997). In addition to this, recent studies (e.g., Morello *et al.*, 2000; Fazal, 2000; Nizeyimana *et al.*, 2001; Hathout, 2002; Hasse and Lathrop, 2003) show that urban development consumes highly productive soils.

The urbanizing process consumes land resources, reducing the possibility to develop other traditional and more sustainable land uses. Or even affecting the ecological properties of the areas were urbanization expands. In most Mediterranean countries, urban spread has been done in flat coastal plains, where initially most attempts have been made to strike the most beneficial balance between development and preservation of natural and agricultural lands (Van Teeffelen, 1984). The hypothesis that degradation and mismanagement of many coastal areas continues (European Comission, 1999) has yet to be validated.

In the last decades, soil degradation induced by urban growth has become one of the most significant environmental threats in Mediterranean countries, mainly in coastal environments (Leontidou *et al*., 1998; Plan Bleu, 2003). Soil loss through surface sealing under housing and transport infrastructures it's a critical environmental issue leading to desertification, an advanced stage of land degradation. As a consequence the soil, a non-renewable resource, loss its multifunctional role (Blum, 1998) and therefore, the process of urban growth finally lead in much of these areas to the total and irreversible disappearance of soils dedicated to non urban uses.

One of the main driving forces of land use and land cover changes is caused by urbanisation (Hubacek and Vazquez, 2002), that modify and fragment the structure and organisation of rural landscape attributes and create new ones (Poudevigne *et al*., 1997; Antrop, 2000; Milesi *et al*., 2003). According to various researchers (e.g., Coccossis, 1991; Weber and Puissant, 2003) urbanisation processes, including residential, industrial and infrastructure development, seems to have been the single most instrumental process of change for the European Mediterranean regions. In recent years land use-cover in Mediterranean environments, mainly in coastal areas, is changing at a high rate.

Contemporary socio-economic history of coastal Mediterranean regions, such us the Valencia Region (Spain), has led to considerable land use-land cover transformations causing, in some cases, the irreversible loss of prime farmland. Evaluation of soil sealing by urbanisation is then a key element to understand soil degradation and the disappearance of agriculture or forestry land. Therefore loss of soil by urban growth constitutes an indicator for assessing land degradation (Hoobler, *et al*. 2003; Tullock, *et al*. 2003) and desertification in the Mediterranean basin (Sommer *et al*., 1998).

This work inserted within a study on land use-land-cover and soil degradation of metropolitan areas in the Valencia Region, presents the preliminary results on the urban-non urban dynamics since 1956 to 1998 in the municipality of Alicante, the second largest city in the region.

STUDY AREA

The municipality of Alicante is located in the centre, by the eastern littoral band, of the province of Alicante in the Spanish Valencia region. Together with nine more municipalities it is a part of a higher order territorial unit, known as the *Comarca del Alicantí* (Figure 1). Alicante lays on the eastern most extreme of the Betica Mountains. From there to the Mediterranean shores the relief is descending gradually, according to three mountain belt systems, in an intricate arrangement of dissected substructures of small mountain ranges, "*sierras*", and valleys that conform to the typical littoral eastern Iberian Mediterranean shores.

Most of Alicante has slopes above 5%. Further, almost one third is above 7% of slope; being the western and northern most part of it above 15% or even lying on steeper slopes (Padilla, 1998). Within this topographic structure fluvial lower plains of recent formation are found. From the northern mountain ranges the fluvial dissection is responsible for the ephemeral stream (*barranco*) and ephemeral river (*rambla*) systems that contribute to the final formation of the alluvial plains.

The study area has a typical dry semiarid Mediterranean climate with an annual average temperature about 17ºC and an annual rainfall of 300 mm, very irregularly distributed through out the year and with a major peak of high intensity rainfalls usually recorded during autumn. A second minor rainfall season is also registered in spring. The shortage of rainfall and its concentration in few days over the year gives a considerable amount of clear sunny days, with almost 3000 hours of sun per year (Pérez Cueva, 1994).

From the environmental point of view, both climate and topography constitute the two main elements that can determine the model and pattern of urban expansion, reinforced by the attractiveness of the see facing eastern part of the municipality.

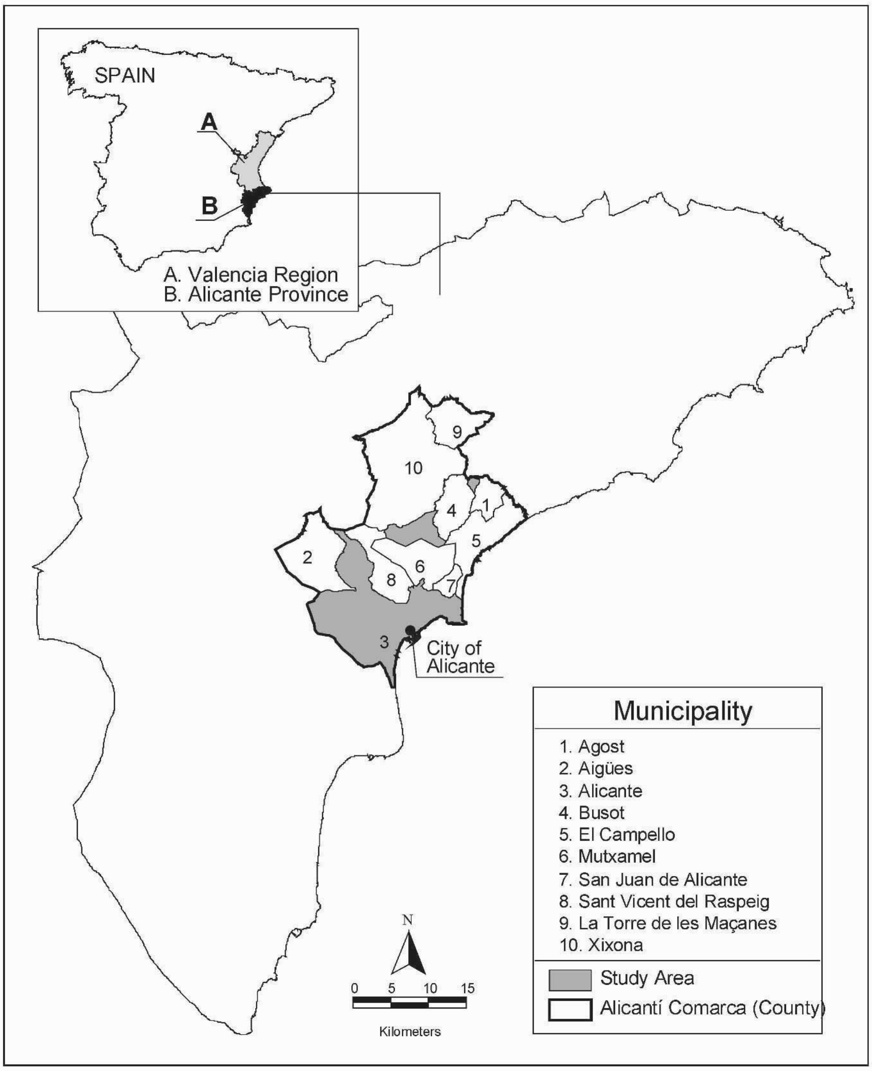


Figure 1. Location of the study area

METHODOLOGY

The analysis of urban growth has been implemented into a vector Geographic Information System (GIS) structure (Burrough and McDonnell, 1998) according to a three major step approach (Figure 2).

First, data sources for feature extraction were identified. Although there exists alternative data sources that could allow the task of soil sealing feature extraction such as maps and satellite imagery, in this work aerial photographs have been used. With respect to satellite data, it is true that nowadays products with very detailed resolution are already available (Neubert, 2001). Nonetheless the high cost of such images together with the inexistence of the same sources for historical dates, and the necessity of harmonisation to improve data consistency and comparability, make feasible the use of aerial photographs that has been proved effective in studies of similar nature (e.g., Taylor *et al*., 2000; Fricke and Wolff, 2002; Hathout, 2002; Cheng and Masse, 2003). Thus, three sets of panchromatic aerial photographs for the years 1956, 1985 and 1998 at scales 1:33 000 (1956), 1:30 000 (1985) and 1:25 000 (1998) constituted the main data sources for mapping land use-cover changes.

The data input and database construction phase and management, consisted of high resolution scanning with sufficient detail for delimitation of small urban features such as isolated new housing and narrow (around 2 m wide) streets and roads. After scanning, all aerial photographs were georeferenced and a single composite mosaic made for each year. Georefencing was the result of combining the scanned photographs, a common set of control points and a base digital topographic map at scale 1:10 000.

Finally geometric (polygon) and semantic databases (tables with attributes) were constructed for each layer of information, or year, by aerial photograph interpretation technique (Bird *et al*., 2000) and on screen digitising. Information from the 1998 aerial photographs were digitised as the reference urban growth data layer, allowing on one hand feature recognition and visual training of the panchromatic sources, and on the other a support for polygon delimitation of the rest of historical sets. Attribute definition for polygon assignation where defined according to two major classes: urban (that where subdivided into low density when buildings where no compacted, high density such as residential blocks in cities) and non-urban.

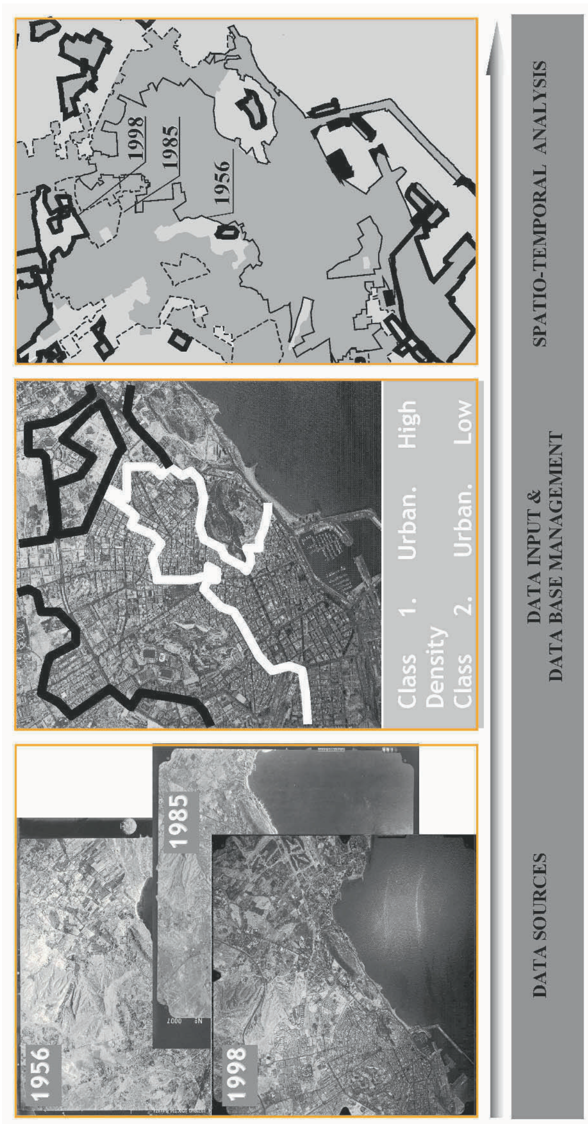


Figure 2. Methodological structure for the study of soil sealing by urban growth in the municipality of Alicante

Once both semantic and geometric data bases were constructed, it was possible to proceed with the third phase of the methodology, which consists of spatial and temporal analysis. Two main criteria were taken into account: a synchronic (at one date) spatial analysis was undertaken for each year followed by a diachronic map comparison to define spatio-temporal trends. To assess and illustrate the results of the spatial and temporal changes of soil loss by urban growth, maps and overlays together with synthetic tables were produced as GIS outputs.

RESULTS AND DISCUSSION

Factors affecting the growth of urban spaces are related to both environmental and socio-economic variables. The former could be restrictive (such as very steep relief, flooding areas, etc.) or prone to urban growth expansion (such as littoral position, or even good weather -dry and worm- conditions). On the other hand, socio-economic factors would reinforce urban growing; for example, the recent tourist industry development, the political and administrative provincial capital status and the progressive population increase are factors that would increase urban expansion potentials.

From an environmental perspective, the municipality is structured by a dense ephemeral streams and ephemeral rivers descending from the highest western steeper slopes (Figure 3).

Such topographic distribution is very limiting for urban dissemination in the inner and central mountain formations, or at least will determine an urban structure of low density urbanisation. While over the flat lands, where the original city of Alicante settlement is found, the urban growth is related to a high density expansion model. Other aspects such as climate and see facing slopes will reinforce the low density pattern of the steeper areas.

In fact such two major types of urban growth dynamics have been developed since 1956 in Alicante. One is related to a type of dispersed settlement that nowadays could be explained by the tourism and second residence expansion. This low density urban growth had a higher moment of expansion in the period 1956-1985 when there was an increase equivalent to 5% of the total municipal area (Table 1).

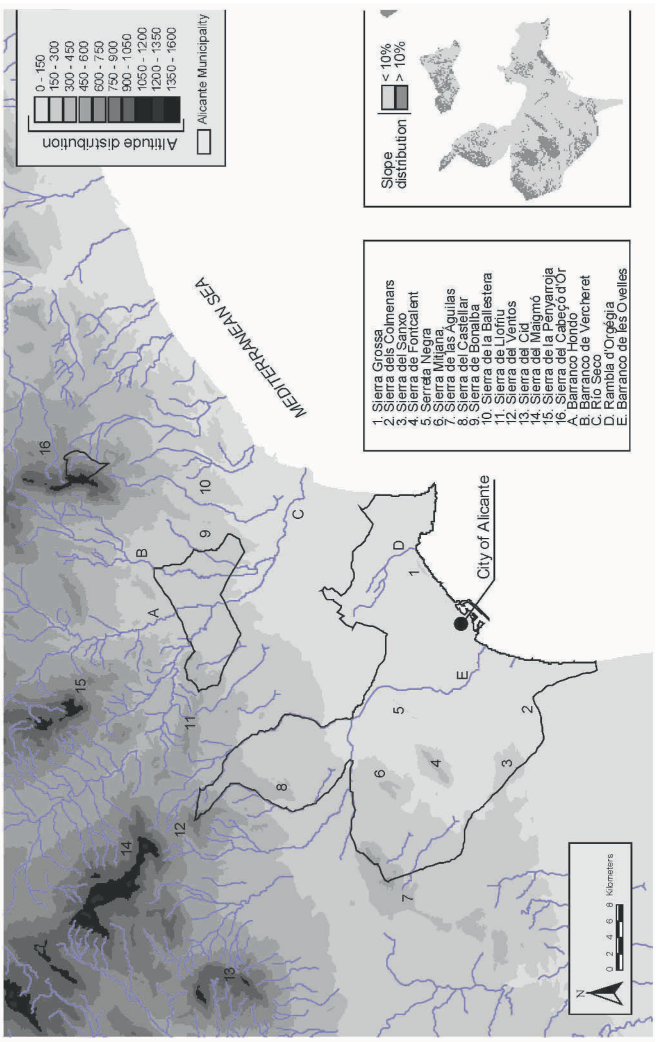


Figure 3. Relief distribution of Alicante municipality and surroundings

Table 1. Urban growth types and synthetic dynamics of the municipality of Alicante

TYPE OF LAND COVER		1956		1985		1998	
		Ha	%	Ha	%	Ha	%
Urban	High density	618	3.1	1,738	8.6	2,325	11.6
	Low density	371	1.8	1,399	7.0	1,789	8.9
	Total	989	4.9	3,137	15.6	4,114	20.5
Non urban		19,088	95.1	16,940	84.4	15,963	79.5
Total		20,077	100	20,077	100	20,077	100

This period is coincident with the intensive decades of the constitution and consolidation of the tourism industry of the area. From 1985 to 1998 the low density urban growth has signified an additional 1% (1,553 Ha). This type of settlement has occurred in the inner continental part of the municipality, with two different foci of expansion: one in the west and a second, closer to the Mediterranean, in the north (Figure 4).

In 1956 most of the urban spaces were of high density, being concentrated around the original city of Alicante. Very little high density development can be found toward the east on the shore line that will be a second element of expansion in coming years. The low density urban spatial distribution in 1956 is scarce. Its major area of representation is located between the two high density elements above mentioned. The rest of low density surfaces are scattered over the study area.

In 1985 the spatial trends of soil sealing distribution by urban expansion is highly different. The major area around Alicante city is now growing assuming a crescent shape. Also there is an increment of such features alongside the shore line (north and south) and towards the confluence with the second spot of high density identified in 1956. The low density pattern is now more evident due to the fact of its important increase in surface. The original trend to connect the city of Alicante with the coast line by the northeast is now consolidated; while it can also be found a larger concentration by the northwest of the municipality.

In 1998, the trends described for the image of 1985 are now well consolidated: expansion and compaction according to the crescent shape of the city of Alicante, occupation of the shore line by high density buildings, concentration of low density areas between the city and the second point of high density on the coast line and enlargement of the low density residential surfaces on the west of the area.

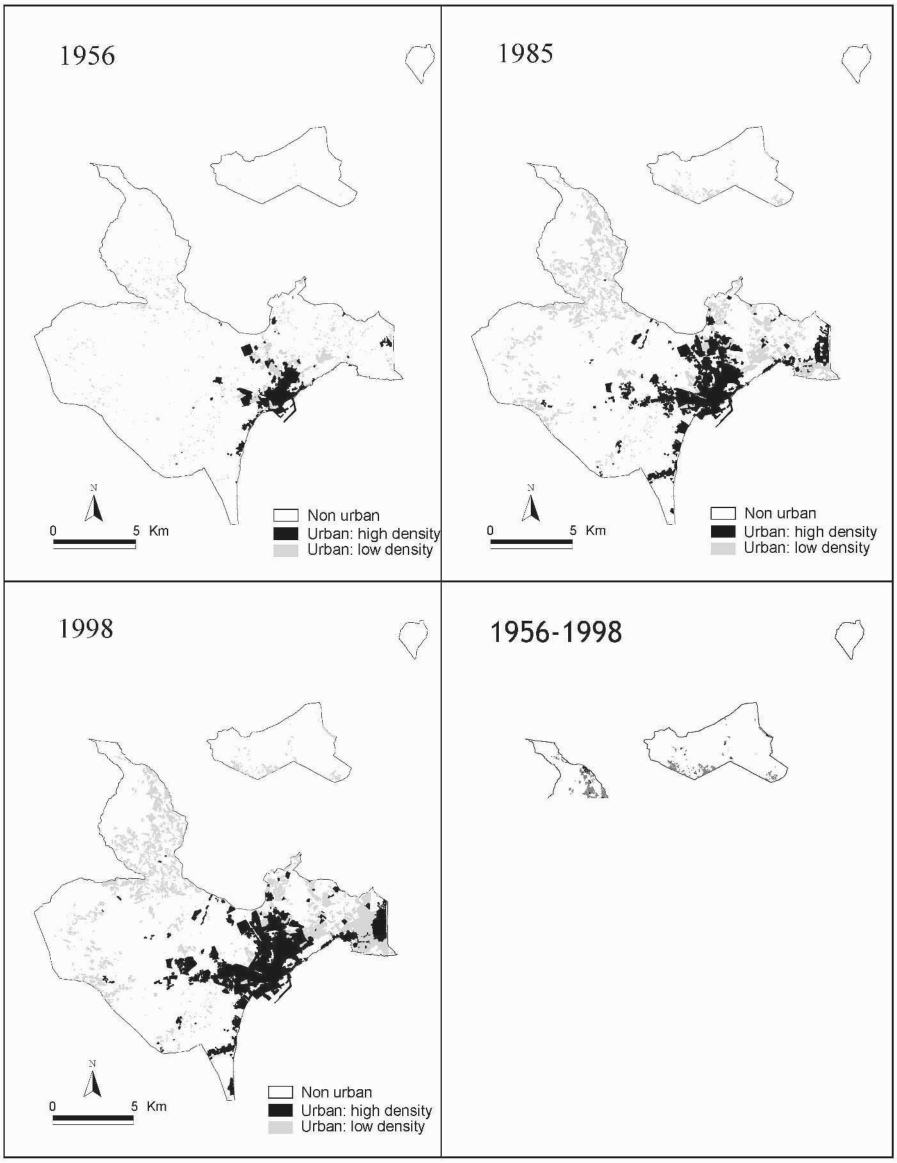
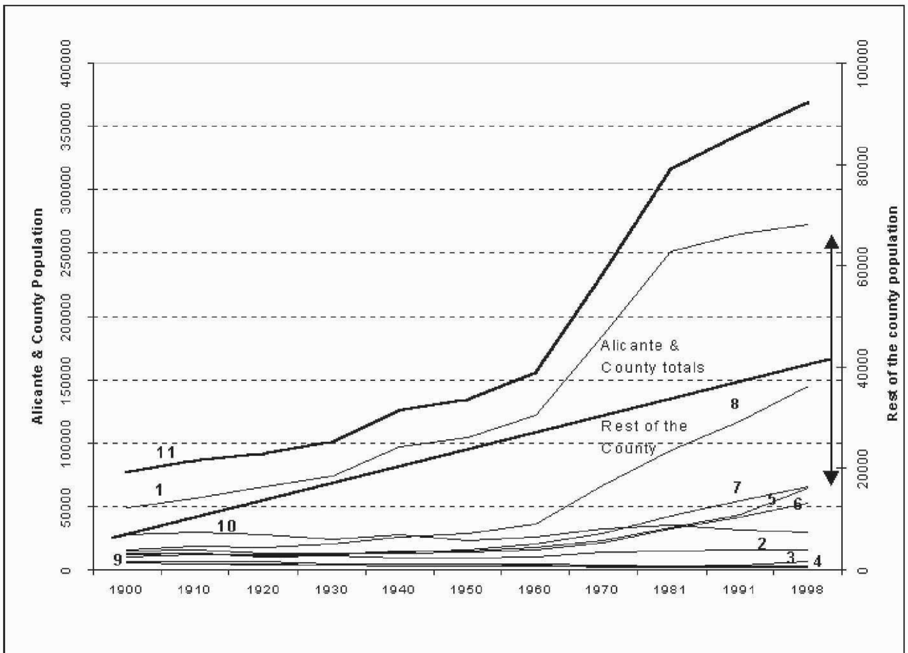


Figure 4. Spatio-temporal distribution of urban expansion in Alicante

The model of urban growth of Alicante is synthesised by the 1956-1998 image (Figure 4). Nowadays the municipality has a semi-polynuclear high density settlement with at least two differentiated points of expansion: the city of Alicante and the eastern area. On the other hand the low density enlargement has been done mainly in the inner parts of the municipality, resulting in a scattered pattern of residences over the western hills. For the period analysed, constant population increase seems to be a synthetic expression of the socio-economic forces behind the urban sprawl experienced in the municipality (Figure 5). This is so for the first 20 years analysed. Since 1980, there must be other reasons (urban cultural changes in the housing demand, financial investments for the development of commercial, leisure and sport areas, etc.) that explain the steady rising of urban surface while population growth stops or even decrease.



1. Alicante	5. El Campello	9. La Torre de les Maçanes
2. Agost	6. Mutxamel	10. Xixona
3.Aigües	7. San Juan de Alicante	11. County totals
4. Busot	8. San Vicente del Raspeig	

Figure 5. Population trends for the *Alicantí Comarca*

For the county, the topography restriction will explained the differential population growth in mountain municipalities (Agost, Busot, Aigües, La Torre de les Maçanes and Xixona), with very low population increase rates. On the contrary the littoral less steep municipalities (Alicante, San Vicent del Raspeig and San Juan de Alicante) present high rates of population growth. Then it could be suggested that population trends -associated with the topographic argument- will prevent massive urbanization. Therefore the urban growth model, apart from traditional settlements, would be more of the low density type.

In this way it can not be forgotten that Alicante is the province capital city, characterised by it's political, administrative and services role. It is also the main destination of international charter flights (mostly from northern UE countries) because its strategic location in one of the largest tourist areas of Spain (Costa Blanca) based on the sun and beach binomial. Consequently, the city of Alicante has experienced, since its original settlement, an expansion based on the population increase and its particular socio-economic features.

CONCLUSIONS

Land degradation processes resulting from human activities constitute the most important environmental threat in the Mediterranean countries. The final phase of the process leads to desertification. Among factors causing soil degradation one of the most important, although less studied in Mediterranean environments, mainly in coastal areas, is soil loss through urban development and construction of transport infrastructure, phenomenon known as soil sealing.

The urban land transformation experienced by the municipality of Alicante since the 1950s have produced the irreversible loss of considerable part of its surface. The intensity of expansion was significant between 1956 and 1985, while since that date until 1998, the trends were consolidated. In all it has extended from 5% of its territory in 1956 to 20.5% in 1998. Results show that there has been a substantial loss of soils devoted to both agricultural land uses and natural open spaces. Urban growth can be differentiated into three distinct spatial patterns:

1. Edge compact enlargement of the city boundaries including growth following the main road network.
2. Compact new urbanisation alongside the coast.

3. Colonisation by groups of individual residences (low density urban growth) mainly over both continental open spaces.

The process, although it is similar to other main municipalities of the Valencia Region such as Valencia city (Pascual Aguilar, 2002; Pascual Aguilar *et al*., 2002), has its own characteristics; being the low density development the most important. Topography is the most relevant force behind restrictions to a denser urbanisation. While in the municipality of Valencia, located in a very flat alluvial plain, the only restriction is the existence of the Albufera Lagoon, declared as a Natural Park. In the rest of the municipality rates of urban growth are always related with high density urbanisation, and the proportion of land covered by artificial surfaces is then higher than in Alicante municipality.

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LAND USE CHANGE DETECTION AS A BASIS FOR ANALYSING DESERTIFICATION PROCESSES: A CASE STUDY IN TABERNAS (ALMERIA, SPAIN)

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ABSTRACT

This contribution proposes an integrated approach to detect and quantify land-use and land-cover changes as a basis for studying and predicting changes in environmental processes leading to desertification. The approach has been applied in Tabernas (Almería, Southeast Spain), a representative area of the Mediterranean region where a combination of extreme environmental conditions and modifications of the land-use pattern that occurred in the last decades have led to increase the risk of desertification.

The approach is based on multi temporal records of remotely sensed data and field survey. Sets of aerial photographs taken in the fifties (1956), the eighties (1981) and the nineties (1995) were used to map land use and cover in the three different periods of the last fifty years. The results indicate that from 1956 to 2000, a total area of 5218 hectares of land was subjected to change in land use. The main land cover type that was subjected to change was dry farming. Throughout the past four and half decades 2507 hectares (32%) of dry farming has changed into different land use types, of which 1447.7 (57.7%) hectares changed to irrigated farmland, 857 (34%) became abandoned and about 202 (8.3%) were subjected to various activities (infrastructures, industries, etc.) that have left the area without a vegetation cover. The abandoned areas have evolved to areas with a weed type non-permanent bush cover, which is totally different from the natural cover in the region. The land abandonment and the change from dry farming to irrigation seem to exert pressure on the environment, that can lead to an increase in desertification processes such as soil erosion, salinisation and pollution. Most of the recent irrigated farms are on slopes ranging in inclination from 2 to 8%. Important erosion processes can occur both on these slopes and on abandoned areas depending on other influencing factors (e.g., soil erodibility).

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INTRODUCTION

Desertification is one of the most serious environmental issues at global, national, regional and local scales (UNEP, 1992; Imeson, 1996). According to the UN Convention to Combat Desertification (UNCCD) (UNCED, 1994), desertification means "land degradation in arid, semiarid and dry-subhumid areas resulting from various factors, including climatic variations and human activities". The main processes leading to desertification include the removal or destruction of the vegetation cover, soil salinization, soil acidification, soil contamination, loss of soil organic matter, soil compaction, and water and wind erosion (FAO/UNEP, 1984). The major effects of desertification are soil degradation, depletion and contamination of surficial and underground water, landscape deterioration and loss of biodiversity.

The European Mediterranean region, which covers Portugal, Spain (except the northern part of the country), the Southeast of France and most of Italy and Greece (Joffre *et al*., 1995), is prone to desertification because of its particular environmental conditions (UNCED, 1994): seasonal drought, high rainfall variability and intensity, uneven and steep relief, and abundance of soils and rocks susceptible to erosion processes. Furthermore, human pressure accelerates the desertification risk in this region. Over the recent decades, the land-use pattern in the European Mediterranean region has changed because of agricultural intensification, even in marginal areas, and expansion of industrial-urban uses, including tourism (UNEP, 1986; Coccossis, 1991). Consequently, many environmental issues have emerged, including destruction of vegetation cover, soil erosion, soil compaction, soil salinisation, soil pollution, soil "asphaltisation" (Rubio *et al*., 1998), loss of biodiversity, landform changes, landscape deterioration and surficial and underground water pollution and depletion.

Aggravation of these environmental issues has led to an increase of the risk of desertification in extensive areas of the European Mediterranean region (UNCED, 1994; Rubio *et al*., 1998; Yassaglou, 1998). Therefore, the analysis of land use changes and their environmental consequences has become an urgent need for this region.

This contribution shows an integrated approach to detect and quantify land-use changes as a basis for studying and predicting changes in environmental processes (e.g., soil erosion) leading to desertification. The approach has been applied in Tabernas (Almería, Southeast Spain), which is a representative area of the Mediterranean region, where a combination of extreme environmental conditions and modifications of the land-use pattern that has taken place in the last decades can lead to an increase of the risk of desertification.

THE TABERNAS STUDY AREA

The study area is located in southeastern Spain, within the province of Almeria, indicated in Figure 1. It covers about 50 km^2. The city of Almeria, with a population of 145.000, is the nearest large urban agglomeration located 37 km south of Tabernas, which is the largest town in the study area with a population of 3.241 inhabitants.

The Tabernas valley occupies the centre of the study area, where most of the human activities take place, and it is limited by two E-W trending mountain chains: the Sierra de los Filabres to the north, and the Sierra Alhamilla to the south. The Desert of Tabernas, which is considered the only true desert in the whole of Europe fulfilling the criteria of a desert definition, is located in the western part of the study area. Both the Desert of Tabernas and part of the Sierra Alhamilla are now protected natural areas.

Figure 1. Location of the study area

The dominant land cover types in the area are bush and grass cover with and without trees. The main land use is agriculture (barley and few irrigated crops), which, on the other hand, has serious limitations because of climatic and topographic conditions. However, irrigated olive and almond plantations have been introduced during the last decade. Other activities are grazing and mining, but these were more important in the past. Mining is now limited to a few gypsum quarries and many abandoned mines can be found in the area. Industry has little importance, although the movie and entertainment industry has attracted many visitors in the last few years. In fact, the tourism sector is gaining importance and can be one of the main economic activities in the future.

Tabernas is a representative example of arid areas, within the European Mediterranean region, where a combination of environmental restrictions (e.g., seasonal drought, high rainfall variability and intensity, uneven and steep relief, and abundance of soils and rocks susceptible to erosion processes) and human induced land degradation processes (e.g,. intensification of agriculture, industrial-urban expansion, land abandonment) can lead to increase the risk of desertification. For this reason, there was selected as a pilot study area to apply an integrated approach to detect and quantify land-use changes as a basis for analysing desertification processes. The particular environmental conditions of the area, which are responsible for its inherent susceptibility to desertification processes, are especially visible in the spectacular bad-lands of the Desert of Tabernas.

APPROACH FOR LAND USE CHANGE DETECTION OF LAND-USE

The integrated approach used to detect and quantify land-use and land-cover changes, shown as a flowchart in Figure 2, is based on photo interpretation of remotely sensed data (aerial photographs) and on its integration with ancillary field and map data. It was adapted from the methodology followed by Taylor *et al*. (2000) to monitor landscape changes in the National Parks of England and Wales, who used aerial photo interpretation and Geographical Information System (GIS). This methodology was found to be suitable for the similarities in type of remotely sensed data used (aerial photos) and its simplicity. Change detection using satellite data can also provide timely and consistent estimates of change in land use trends and has the additional advantage of ease of data capture into a GIS (Prakash and Gupta, 1998). However, in this study, due to the small size of the study area and the complex nature of the land use pattern, aerial photos were found to be more convenient for change detection, mainly of human induced changes. In any case the interpretation of remotely sensed data always needs field ground truth and possibly verification with aerial photos. Sets of aerial photographs taken in the fifties (1956), the eighties (1981) and the nineties (1995) were used to map land use and cover in the three different periods of the last fifty years.

The last set of aerial photos, of 1995, and the map generated from them, were taken as a contemporary situation, i.e. that of the year 2000 at the time of the study, after updating by field survey. Aerial photo interpretation (API) maps produced from the interpretation of 1956 and 1982 aerial photos were used to trace back changes. Data analysis and integration were done by applying various GIS processing techniques using the ILWIS® package (Integrated Land and Water Information System, ITC, 1997).

Mapping Procedure

The mapping process started with the visual interpretation of the sets of aerial photographs. Aerial photo interpretation allowed the delineation and demarcation of land-cover and land-use limits. Conventional stereoscope and computer aided multi-windows on-screen analysis were the two visual aerial interpretation techniques employed. In addition to the aerial photos, the corresponding topographic maps of the years 1950, 1985 and 1997 were also used as an aid where photo interpretability was low.

After orthorectifying the photos, photo mosaics were constructed for each set. This implied several operations such as digitising and polygonization that were carried out using the GIS facilities.

A database containing the information extracted from the three data sets was generated with the GIS to calculate and assess changes. The thematic information that corresponded to each year was added to the GIS database constructed during the mapping procedure by sequentially joining all the three attribute tables, constructed for each data set, two at a time. This provided additional information on soil, geomorphology, slope, and other ancillary data that were entered for each polygon. Using the attribute table maps were generated for each set.

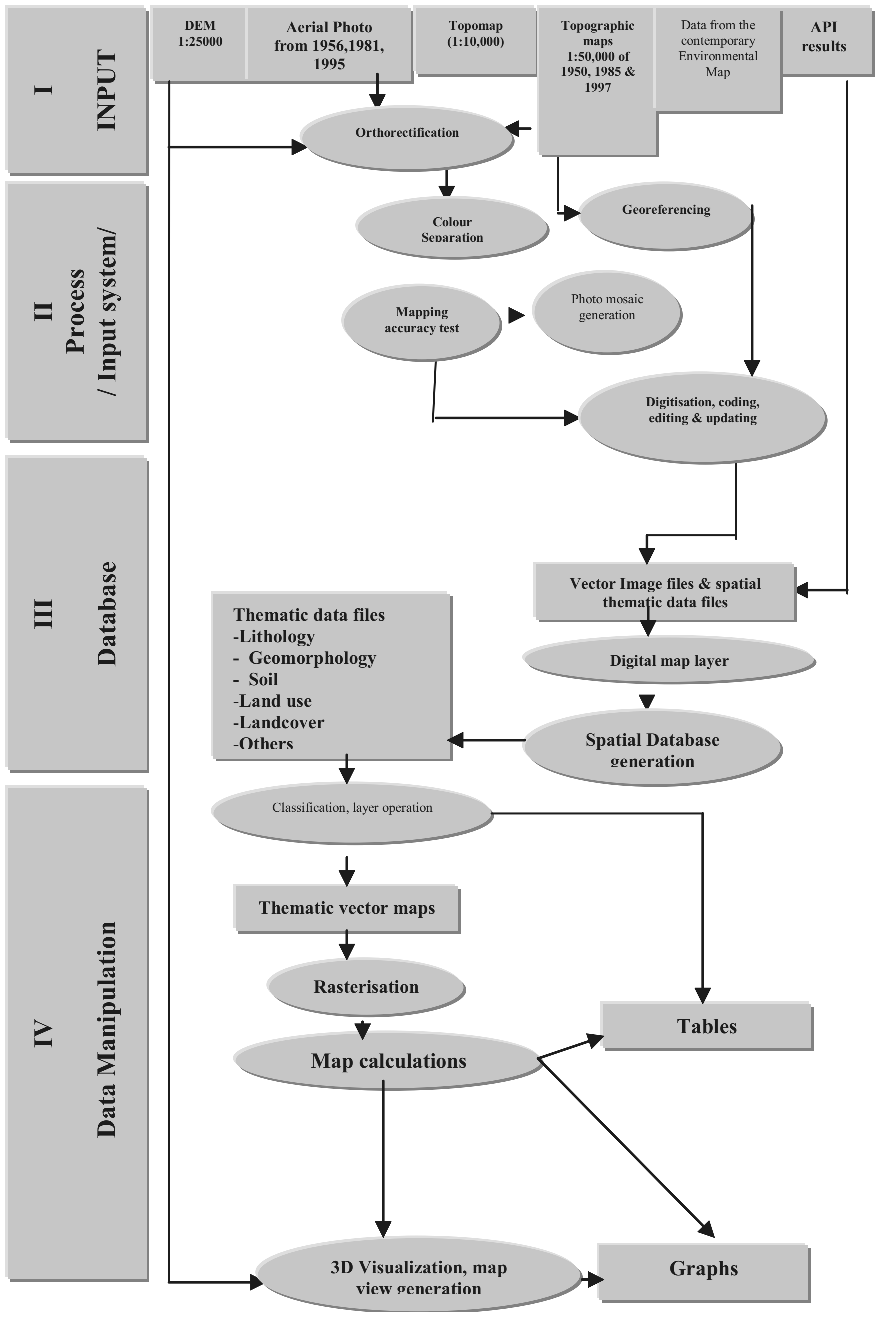

*Figure 2.*Land-use change detection approach followed in ILWIS®(ITC,1997)

Land Use Change Detection

Changes are the differences between the values for each km^2 in the corresponding years. Areas or polygonal features were represented as a set of contiguous 5m x 5m square cells in the GIS. Net changes are differences between the pixel totals for a land use type at the corresponding dates. Gross change is the sum or number of the pixel lost and gained by a given land use type between two specified years. This allowed identifying the nature of the change.

In order to perform the map calculation for quantifying land-use changes, the same land-use classification categories or classes were used to classify the three API maps.

RESULTS AND DISCUSSION

Figures 3, 4 and 5 show the API land use maps corresponding to the years 1956, 1981 and 2000, respectively.

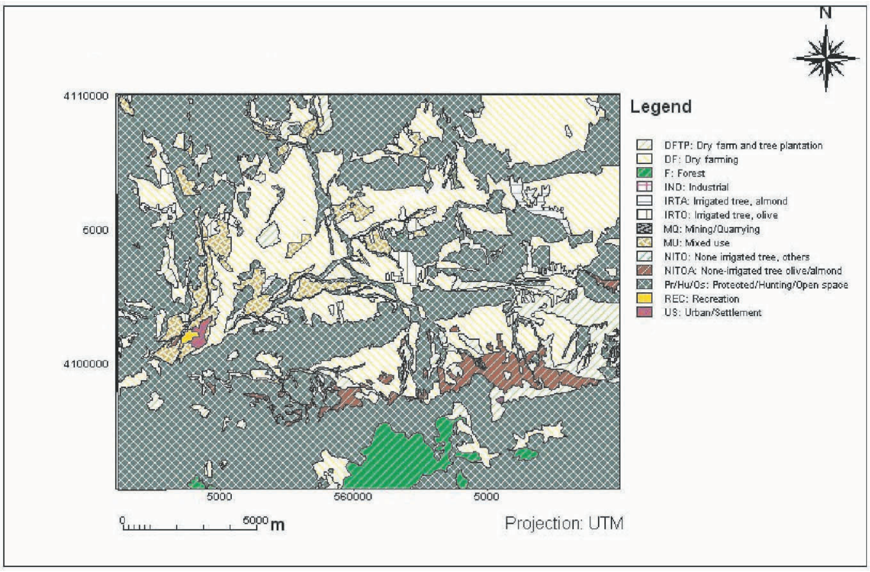

Figure 3. API Land use map of 1956

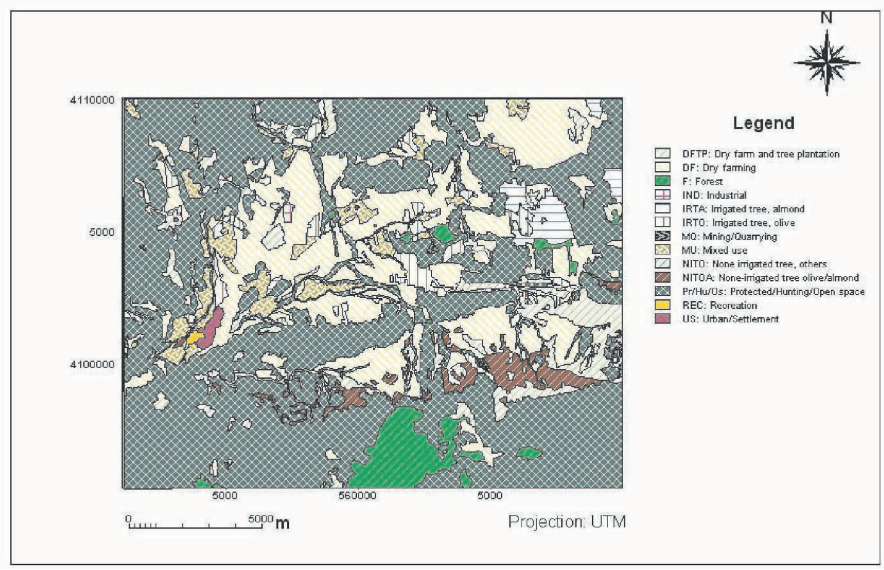

Figure 4. API Land use map of 1981

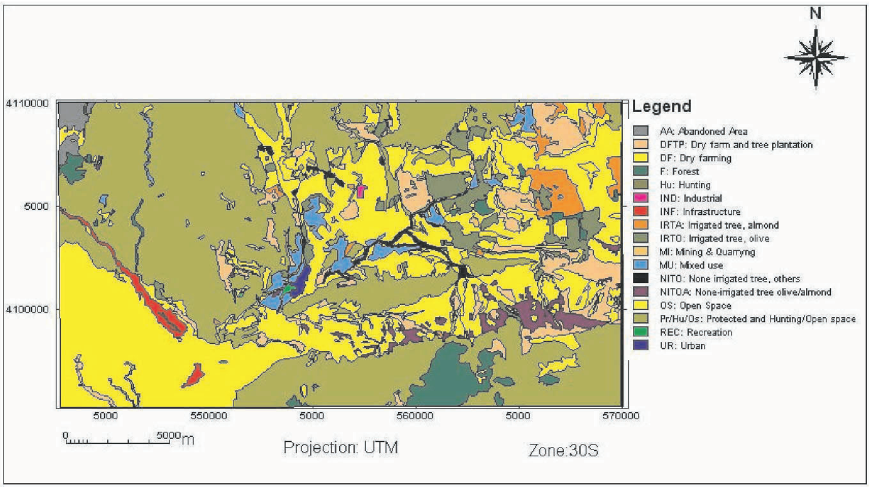

Figure 5. API Land use map of 2000

Table 1 summarises the land-use classes identified for the three periods and shows the gross changes that have occurred between the three years or corresponding periods.

Table 1. Gross land use changes that occurred in Tabernas (Almeria, Spain) between 1956, 1981 & 2000

Landuse Type	Year/Area in ha.			Gross Changes/area-ha.			Gross Changes in Percent		
	1956	1981	2000	2000-1981	2000-1956	1981-56	1956 to 1981	1956 to 2000	1981 to 2000
Dry farm and tree plantation	1582.63	1619.92	1626.97	7.05	44.34	37.29	2.36	2.80	0.43
Dry farming	7858.72	6418.69	5351.67	-1067.03	-2507.03	-1440.03	-18.32	-31.90	-16.62
Forest	798.25	1023.12	1038.94	15.82	240.69	224.87	28.17	30.15	1.55
Industrial	0.00	26.13	26.13	0.00	26.13	26.13			0.00
Irrigated tree, almond	196.37	540.90	786.38	245.49	590.02	344.53	175.45	300.47	45.38
Irrigated tree, olive	398.24	761.14	1337.98	576.84	939.74	362.90	91.13	235.97	75.79
Mining/Quarrying	7.93	19.49	35.32	15.83	27.39	11.56	145.78	345.43	81.23
Mixed use	1085.70	1117.22	1209.34	92.12	123.64	31.52	2.90	11.39	8.25
None-irrigated tree, others	12.35	52.32	60.06	7.75	47.71	39.97	323.61	386.33	14.81
None-irrigated tree olive/almond	751.32	748.24	748.26	0.02	-3.06	-3.08	-0.41	-0.41	0.00
Protected/Hunting/Open space	14957.63	15289.91	15396.03	106.12	438.40	332.28	2.22	2.93	0.69
Recreation	25.20	28.60	28.60	0.00	3.40	3.40	13.50	13.50	0.00
Urban/settlement	47.72	76.38	76.38	0.00	28.66	28.66	60.07	60.07	0.00
Total/Overall increase	27722.06	27722.06	27722.06	2134.07	5218.42	3084.40	865.62	1422.89	244.74

From 1956 to 2000, a total area of 5218 hectares of land was subjected to change in land use, of which 41% was within the past two decades.

Dry farming has been the most modified land-use type in the study area. Throughout the past four and half decades 2507 hectares (32%) of the dry farmland has changed into different types of land use, of which 1447.7 (57.7%) hectares changed to irrigated farmland, 857 (34%) became abandoned and about 202 (8.3%) was subjected to various activities (infrastructures, industries, etc.) that have left the area without a vegetation cover. The irrigated land has grown by 98% since 1956, 54% of which since the year 1981. The "Forest" class has shown the considerable increase of 247 hectares (23.7%) due to the pine tree plantation on the mountains for controlling soil erosion and the eucalyptus tree plantation in the valleys for wood production. The mining activity and other land uses such as urban use and industrial development, which occupy a relatively small area, have also shown a considerable increase. Recreation and "Protected/Hunting/Open Space" class of areas have shown a slight increase. Non irrigated trees other than olives and almonds have shown an increase whereas non irrigated olive and almond trees have showed a small decrease.

The land abandonment and the change from dry farming to irrigated trees, which are the main land use changes identified from 1956 to 2000 in the study area, seems to exert pressure on the environment, that can lead to an increase of desertification processes such as soil erosion, salinisation and pollution.

The abandoned area has evolved to an area with a weed type non-permanent bush cover, which is totally different from the natural cover in the area. This non-permanent bush cover offers less protection to the soil against the runoff than the natural vegetation. Moreover, land abandonment also means the abandonment of soil conservation practices such as terracing systems. All this can lead to an intensification of soil loss by erosion processes, especially in areas with high slopes.

Most of the recent irrigated farms are on slopes ranging from 2 to 8%. Important erosion processes can occur on these areas depending on other influencing factors (e.g., soil erodibility). In fact, most of the irrigated lands have extended on Neogene sub-marine materials. Soils developed on these materials (e.g., Regosols, FAO, 1988) show a high erodibility, which can lead to moderate soil erosion processes. But the recent advancement of irrigation lands to higher slopes with the lack of good soil conservation practices such as farming following contour lines and terracing systems, as it occurs in many areas, could mean an intensification of the soil loss by erosion processes.

On the other hand, it must be highlighted that Neogene sub-marine materials have soluble salt components. Therefore, the extension of irrigation schemes on these materials can also lead to an increase in soil salinisation as a result of the capillary rise of water in the extremely high-evaporation conditions of the study area.

The increasing use of chemicals, such as pesticides and fertilisers, due to the intensification of irrigated farming, means also to increase the threat to the environment.

As irrigation is intensified, another important potential threat to the environment is the over-pumping of the groundwater. The change in land use has brought change in water consumption and water schemes. A good indicator for this trend is the increase in the water scheme distribution. The 23 water points that were present in 1956 have grown to 191 by the year 2000. The average increase from 1956 to 1981 was almost 2 water points per year. During the period between 1981 and 2000 it increased to more than 6 water points per year. This can lead to an important depletion of underground water resources that make irrigation unsuitable in the near future.

Mining and quarrying can also lead to increase the desertification processes in the study area. The sand quarry near Tabernas is expanding and the vegetation cover around this site is of non-perennial type that offers less protection to soil against runoff than natural vegetation. Soil erosion can therefore increase in this area. The iron mine in the eastern part of the study area and the gypsum quarry that can be seen on the road from Tabernas to Sorbas are now abandoned. No land reclamation and restoration have taken place so far in those sites. The acid drainage that comes out of the iron mine might have already contaminated the down stream hydro-geologic system.

However, the intensification of the desertification processes outlined here associated to the land use changes occurred in the study area in the last decades need to be corroborated trough appropriate studies. Further research would imply, for instance, an analysis of erosive morphologies to see if they have increased in the areas where the main human-induced land use changes have taken place. The analysis of salt and contaminant contents of soils under irrigation and the comparison with the contents of soils still used for dry farming would also become necessary.

CONCLUSIONS

An integrated approach based on multi temporal records of remotely sensed data and field survey to detect and quantify land-use changes as a basis for studying and predicting changes in environmental processes leading to desertification has been proposed and applied. The application of the approach in a GIS environment facilitates the assessment of land use changes between two specified years. Using GIS changes can be easily calculated trough the pixels lost and gained by a given land use type in a specific period. The approach has been applied in a representative area of the Mediterranean region (Tabernas, Almería, Southeast Spain), having identified that a total area of 5218 hectares of land was subjected to change in land use, from the year 1956 to the year 2000. The land abandonment and the change from dry farming to irrigated farmland are the main land-use changes that have taken place in the study area. Taking into account the environmental conditions characterising the areas where these changes have occurred (e.g., slopes ranging from 2 to 8%, high erodibility of soils, extremely high-evaporation) and the management practices associated to irrigation farmland (e.g., intensive use of agrochemicals, over-pumping of the groundwater), what can be predicted is an increase of desertification processes such as soil erosion, salinisation and pollution. Given that the modifications of the land-use pattern that occurred in the last decades in the study area are similar to those identified in the broader European Mediterranean Region, it follows that the approach can be applied to this larger region to assess land-use changes and to predict the consequent increase of desertification processes. However, such predictions need to be corroborated trough appropriate and specific studies, for instance, by analysing whether erosive morphologies have increased in the areas where the main human-induced land use changes have taken place.

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CLIMATE CHANGE, LAND DEGRADATION, AND DESERTIFICATION IN THE MEDITERRANEAN ENVIRONMENT

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ABSTRACT

Until the early seventies land degradation and desertification were not considered a major issue in most Mediterranean regions. Traditional agricultural systems were believed to be able to keep those processes in check. Thus low priority was assigned to research programmes and projects on soil erosion and conservation, preference being given to the impact of farm machinery on soil structure and compaction along with the role of organic matter in the soil.

In the eighties and early nineties the agricultural practices introduced in sloping land under cultivation in the Mediterranean in previous decades were identified as a major contributor to soil degradation. The unprecedented efforts to increase crop yields and maximize profit, made possible by the technological revolution in agriculture, had triggered in the agricultural ecosystem the onset of soil degradation due to hydrological phenomena that proved detrimental both to soil fertility and to the landscape causing devastating and permanent damage. In addition, it was recognized that research activities were too fragmentary to be able to cope with the demands of implementing sound soil conservation measures.

The Mediterranean climate is characterised by hot dry summers and mild wet winters. The region frequently suffers from years of scant rainfall and many areas are afflicted by severe drought. The UK Hadley Centre's global climate model has been run on a monthly basis for the Mediterranean countries to predict the percent variation in rainfall and temperature with respect to mean monthly values. Scenarios developed using the model show that for the wet season (October-March), by the year 2050 rainfall could increase in central

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and eastern Spain, northern France, northern Italy and the Alps by up to 15%, against a decrease of about 10% to 15% in the southern Mediterranean. For the same period, the temperature in the northern Mediterranean is predicted to increase by 1.25° to 2.25°C, compared to an increase of between 1.5° and 2.5°C in the southern Mediterranean. The projections also show that for the dry season (April to September), by the year 2050 rainfall is likely to decrease over much of the Basin. Decreased precipitation is predicted to be accompanied by a rise in temperature of between 1.5 and 2.75°C in the northern regions and 1.75° and 3.0°C in the southern Mediterranean. Reduced precipitation during the summer has a major impact on irrigation and tourism, which both increase the pressure on water supplies during the dry period.

To combat these problems, the European Community (EC), in collaboration with other international organizations, has funded various programmes and projects for mitigating drought and assessing and preventing land degradation and desertification.

In this context, the paper describes the main features and characteristics of some of these programmes and projects and proposes new approaches to environmental policies, in order to:

- assess, forecast and mitigate adverse impacts of drought;
- better understand soil erosion, land degradation and desertification processes;
- identify preventive, protective and remedial measures;
- address quantity and quality of natural resources in an integrated context;
- support innovation and participatory strategies.

The importance and role of institutional strengthening, sound financial and managerial frameworks, availability of human resources involved, research thrust, technology transfer and networking improvement are also highlighted.

Keywords: climate change, land degradation and desertification, EU programs.

INTRODUCTION

Undeniably, during the third millennium the planet Earth will be subjected to pressures hitherto unprecedented in its recent evolutionary history. The “tomorrow’s world” will not simply be an inflated version of the “today world” with more people, more energy consumption, more industry. In spite of enormous advances in our ability to understand, interpret and ultimately manage the natural world, mankind has reached the 21st century in awesome ignorance of what is likely to unfold in terms of both the natural changes and the human activities that affect the environment and the responses of the Earth to those stimuli. Tomorrow will be qualitatively different from today in, at least in three different yet important aspects.

- First, new technology will transform the relationship between man and the natural world. An example is the gradual transition from agriculture that is heavily dependent on chemicals to one that is essentially biologically intensive through the application of bio-technologies. Consequently, the release of bio-engineered organisms is likely to pose new kinds of risks if the development and use of such organisms are not carefully controlled.
- Second, society is likely to move beyond the era of localized environment problems. What were once local incidents of natural resource impairment shared throughout a common watershed or basin, now involve many neighbouring countries. What were once acute, short-lived episodes of reversible damage now affect many generations. What were once straightforward questions of conservation versus development, now reflect more complex interrelations.
- Third, is the impact of climate change. It is nowadays widely accepted that the increasing concentration of the so-called greenhouse gases in the atmosphere is altering the Earth's radiation balance and causing the temperature to rise. This process in turn triggers a chain of events which leads to changes in the hydrological cycle components such as rainfall intensity and frequency, evapotranspiration rate, river flows, soil moisture and groundwater recharge.

All these problems will become more pronounced in the years to come, as society enters an era of increasingly complex paths of the global economy. In this context, European and global environments are closely linked by global processes such as climate patterns, hydrological conditions and socio-economic factors, transcending regional boundaries. Therefore, achieving sustainable development in Europe largely depends on the above factors and on the basic policies adopted by our society in the decades to come.

Research carried out by the International Institute for Applied System Analysis (Stigiani *et al*., 1989) provided new insight into these problems. The focus was on ecologically sustainable development, in terms of both the opportunities available to European society to achieve it, and the constraints imposed on development by the slow adaptive capacities of ecological systems. The time scale was approximately forty years. The study analyzed the environmental implications of alternative socio-economic development pathways with respect to different environmental issues that could become major problems in the future. The main findings can be summarized as follows:

- Sustaining the European environment in the 21st century cannot be fully achieved without sustaining the global environment as the two are inextricably linked.
- Continuation of present trends in economic development and environmental protection in Europe and elsewhere is not sufficient to prevent further deterioration of the European environment.
- In the Mediterranean countries, failure to take effective global actions to control greenhouse gases and deforestation will lead to serious problems of soil degradation and desertification.
- In Europe, only eco-friendly development can hope to mitigate local and regional-scale environmental problems.

CLIMATE AND CLIMATIC CHANGE

The Greenhouse Effect

Over the past centuries, the Earth's climate has been changing due to a number of natural processes, such as gradual variation in solar radiation, meteorite impacts and, more importantly, sudden volcanic eruptions in which solid matter, aerosols and gases are ejected into the atmosphere. Ecosystems have adapted continuously to these natural changes in climate, and flora and fauna have evolved in response to the gradual modifications to their physical surroundings, or have become extinct.

Human beings have also been affected by and have adapted to changes in local climate, which, in general terms, have occurred very slowly. Over the past century, however, human activities have begun to affect the global climate. These effects are due not only to population growth, but also to the introduction of technologies developed to improve the standard of living. Human-induced changes have taken place much more rapidly than natural changes.

The scale of current climate forcing is unprecedented and can be attributed to greenhouse gas emissions, deforestation, urbanization, and changing land use and agricultural practices. The increase in greenhouse gas emissions into the atmosphere is responsible for the increased air temperature, and this, in turn, induces changes in the different components making up the hydrological cycle such as evapotranspiration rate, intensity and frequency of precipitation, river flows, soil moisture and groundwater recharge. Mankind will certainly respond to these changing conditions by taking adaptive measures such as changing patterns in land use. However, it is difficult to predict what adaptive measures will be chosen, and their socio-economic consequences (Dam, 1999).

Concern global patterns the following considerations can be drawn from analysis of the hydrologic and meteorological time series available:

- Average global temperature rose by 0.6 °C during the 20 th century.
- 1990's was the warmest decade and 1998 the warmest year since 1861.
- The extent of snow cover has decreased by 10% since the late 1960's.
- Average global sea level rose between 0.1 and 0.2 meters during the 20 th century.
- Precipitation increased by 0.5 to 1% per decade in the 20 th century over the mid and high latitudes of the northern hemisphere and by between 0.2 and 0.3% per decade over the tropics (10°N to 10°S).
- Precipitation decreased over much of the northern sub-tropical (10°N to 30°N) land areas during the 20th century by about 0.3% per decade.
- The frequency of heavy rain events increased by 2 to 4% in the mid and high latitudes of the northern hemisphere in the second half of the 20th century. This could be the result of changes in atmospheric moisture, thunderstorm activity, large-scale storm activity, etc.
- Throughout the 20th century, land areas experiencing severe drought and wetness have increased.
- CO_2 concentration has increased by 31% since 1750.
- 75% of CO_2 emissions is produced by fossil fuel burning, the remaining 25% by land use change especially deforestation.
- Methane CH_4 has increased by 151% since 1750 and continues to increase. Fossil fuel burning, livestock, rice cultivation and landfills are responsible for emissions.
- Nitrous Oxide (N_2O) has increased by 17% since 1750 and continues to increase. This gas is produced by agriculture, soils, cattle feed lots and the chemical industry.
- Stratospheric Ozone (O_3) layer has been depleting since 1979.

Present-day Climate

In very general terms, Europe's climate regime can be divided into two types: those dominated by rainfall and those dominated by snowmelt. Rainfall-dominated regimes, with maxima in winter and minima in late summer, are found in the West and South, whereas snow-dominated regimes, with maxima in spring and minima in summer or winter, are found in the North and East. There are differences between the rainfall-dominated regimes of western Europe, which are controlled by the passage of Atlantic depressions, and those of southern and Mediterranean Europe. These latter regimes are characterized by winter rainfall that is at least three times the amount that falls during the summer. Indeed, over much of the Mediterranean summer rainfall is virtually zero. This strong summer-winter rainfall contrast is echoed by a pronounced seasonal cycle in almost all climate variables. Rainfall varies from about 1000 mm in the far northerly areas and in those above 800 m, to 250 mm in the southern dry lands where the sequence of wet and dry years is also a characteristic feature of the region. Generally speaking, rainfall has decreased overall since the end of the 19th century, and this can be related to changes in atmospheric pressure and sea surface temperatures.

Climate behaviour may vary greatly over short distances in the Mediterranean, due to the nature of the landscape and the influence of the sea in coastal areas.

Climate Change Scenarios

Current scientific research is focused on the enhanced greenhouse effect as the most likely cause of climate change in the short-term.

Until recently, forecasts of anthropogenic climate change have been unreliable, so that scenarios of future climatic conditions have been developed to provide quantitative assessments of the hydrologic consequences in some regions and/or river basins. Scenarios are "internally-consistent pictures of a plausible future climate" (Wigley *et al*., 1986). These scenarios can be classified into three groups:

- hypothetical scenarios;
- climate scenarios based on General Circulation Models (GCMs);
- scenarios based on reconstruction of warm periods in the past (paleoclimatic reconstruction).

The scenarios of the second group have been widely utilized to reconstruct seasonal conditions of the change in temperature, precipitation and potential evapotraspiration at basin scale over the century. GCMs are complex three-dimensional computer-based models of the atmospheric circulation, which provide details of changes in regional climates for any part of the Earth. Until recently, the standard approach has been to run the model with a nominal "pre-industrial" atmospheric carbon dioxide (CO_2) concentration (the control run) and then to rerun the model with doubled (or sometimes quadrupled) CO_2 (the perturbed run).This approach is known as "the equilibrium response prediction". The more recent and advanced GCMs are, nowadays, able to take into account the gradual increase in the CO_2 concentration through the perturbed run. However, current results are not sufficiently reliable.

Four GCMs have been used to examine climate changes over the Mediterranean Basin due to the enhanced greenhouse effect: the UK Meteorological Office Model (Wilson *et al*., 1987), the Goddard Institute of Space Studies Model (Hansen *et al*., 1994); the Geophysical Fluid Dynamics Laboratory Model (Wetherald *et al*., 1986); and the Oregon State University Model (Schlesinger *et al*., 1989). The models differ as to the way in which they handle the physical equations describing atmospheric behaviour. All models have a realistic land/ocean distribution and orography, all have predicted sea ice and snow, moreover clouds are calculated in each atmospheric layer in all models.

The developed scenarios of the change in temperature, precipitation and potential evapotraspiration, expected by 2050 over the Mediterranean Basin, in response to a 1°C increase in global mean temperature, due to the enhanced greenhouse effect, showed the following features:

- over the region, as a whole, a warming greater than the global mean, both in winter and summer, along with a small increase in precipitation for the winter season and a decrease in summer;
- the warming is indicated to be greatest in the northern, particularly north-eastern, parts of the area.

The calculation of potential evapotraspiration is based on the modified Blaney and Criddle equation and, therefore, the scenarios for this variable reflect the temperature change scenarios. Precipitation changes are complex, reflecting the complexity of present rainfall patterns. In summer the changes lack spatial coherence, due to the fact that for much of the Mediterranean region present-day rainfall is zero, or close to zero, in the summer months. In winter and spring the scenarios indicate higher precipitation in the north and lower precipitation in the south. In autumn the contrast is between the western Mediterranean (a decrease in precipitation) and the central and eastern Mediterranean (an increase).

The UK Hadley Centre's global climate model comprises several layers into the atmosphere and below soil surface and accounts for most of the essential/dominant hydrological processes. The model runs at spatial scale of 2.5° × 3.75° grid squares for rainfall predictions and 0.5°× 0.5° grid squares for temperature. Version two (HadCM2) of this model accounts only for CO_2 impact (not for aerosols impact). All the scenarios are for the time horizon 2050. They are expressed as percentage change (rainfall) or temperature change compared to the average values of the baseline period 1961-1990 (Ragab and Prudhomme, 2002). The UK Hadley Centre's global climate model has been run on a monthly basis for the Mediterranean countries to predict the percent change in rainfall and temperatures with respect to mean monthly values. The IS92a forcing scenario (which assumes an increase in levels of atmospheric CO_2 of 1% per annum) was used. The results show that by the year 2050 for the wet season (October-March), rainfall could increase in central and eastern Spain, southern France, northern Italy and the Alps by up to 15% while in the southern Mediterranean, rainfall will decrease by about 10% to 15%. For the same period, the temperature in the northern Mediterranean will increase by 1.25° to 2.25°C against an increase of between 1.5° and 2.5°C in the southern Mediterranean. Temperature in coastal areas will usually increase to a lesser extent than in inland regions. Results also show that for the dry season (April to September), by the year 2050 rainfall is likely to decrease over much of the Mediterranean especially in the southern parts where it could diminish by up to 25%. Decreased precipitation is predicted to be accompanied by a rise in temperature of between 1.5° and 2.75°C in the northern regions and 1.75° and 3.0°C in the southern Mediterranean, again coastal areas being affected to a lesser extent than regions inland. Reduced precipitation during the summer has a major impact on irrigation and tourism which both increase the pressure on water supplies during the dry period.

LAND DEGRADATION AND DESERTIFICATION

The issue of land degradation and desertification in the Mediterranean has been the subject of debate and research for centuries (Grove, 1986). It is only in recent years, however, that a serious effort has been made to identify and understand these phenomena and their implications. The term “land” stands for a section of the Earth’s surface, with all the physical, chemical and biological features that influence the use of the resource. It refers to soil, spatial variability of landscape, climate, hydrology, vegetation and fauna, and also includes improvements in land management, such as drainage schemes, terraces and other agrobiological and mechanical measures.

The term “desertification” means land degradation in arid, semi-arid and dry sub-humid areas resulting from climate variations and human activity. The most significant aspect of land degradation is the decline of soil fertility and soil structure and the consequent reduction of the land’s carrying capacity for plants, animals and human beings. This leads to widespread poverty, overexploitation and ultimately destruction and abandonment of land.

Soil degradation in sloping Mediterranean lands has deep roots in the past colonization of the hilly lands, first in the search for defendable and salubrious areas and subsequently in exploiting the land for agricultural and pastoral activities to meet the demands of an increasing population (Chisci, 1993). Over the last four or five decades this situation has changed profoundly. Three major factors have transformed life and livelihood. First, there has been a major change in agriculture. Extensive agriculture based on grazing and dry land wheat has given way to intensive agriculture based on tree crops, horticulture and irrigation. This process has produced a spatial concentration of agriculture together with changes in the spatial distribution of the demand for rural labour. Second, profound social change has been accompanied by a dramatic improvement in the standard of living. The rural lifestyle is in its final stages of transformation and migration from the countryside to the city or overseas has matched that in other countries of the world. Third, the growth of tourism and the littoralization of the Mediterranean economy have added to the problems of rural environments. All three factors have led to an emphasis on land-use conflicts and environment degradation.

By the late 1980's a new threat had emerged, in the shape of global warming generated by the enhanced greenhouse effect. Climate variation and drought are intrinsic characteristics of arid and semi-arid environments, and the Mediterranean Basin is no exception. By examining present climate patterns and possible future trends over the region, scientists have been able to investigate (Brandt *et al*., 1996) the relationship between global warming and drought and assess the changing risk of land degradation and desertification processes (Palutikof *et al*., 1994).

IMPACT OF DROUGHT ON A CHANGING ENVIRONMENT

Drought poses a major threat to social and economic life and leads to the degradation of natural resources. Not only does it reduce the production of crops (crop yield), the quality of grass and fodder, essential for maintaining animal production, but it also jeopardizes the constant supply of good quality water. In areas plagued by prolonged periods of drought, the process triggers chain reactions that result in soil exposure, erosion, land degradation and, ultimately, desertification.

In European Mediterranean countries, the risk of land degradation and desertification is now a very real one considering current climate patterns and human interference and the enhanced greenhouse effect will very likely increase this risk in the short term. The main causes of the land degradation and desertification can be summed up as follows(Chisci, 1993):

- move of agricultural systems towards specialized-mechanized hill farming;
- modification of morpho–structural and infrastructural features of the landscape;
- abandoned, previously cultivated, fields and/or farms and their man-made structural and infrastructural elements;
- increase in forest and pasture fire.

Until the early seventies land degradation and desertification were not considered a major issue in most Mediterranean regions. Traditional agricultural systems were believed to be able to keep those processes in check. Thus, low priority was assigned to research programmes and projects on soil erosion and conservation, preference being given to the impact of farm machinery on soil structure and compaction along with the role of organic matter in the soil.

In the eighties and early nineties the agricultural practices introduced in the previous decades in sloping land under cultivation in the Mediterranean, where increased runoff and erosion had begun to be observed, were identified as a major contributor to soil degradation. The unprecedented efforts to increase crop yields and maximize profit, made possible by the technological revolution in agriculture, had triggered in the agricultural ecosystem the onset of soil degradation due to hydrological phenomena that proved detrimental both to soil fertility and to the landscape causing devastating and permanent damage.

After a thorough analysis of the problem the Program Committee for Land, Water Use and Management of the European Commission's Directorate General for Agriculture, concluded that it was necessary to evaluate in more detail the situation in the different of the Mediterranean environments. In addition, it was recognized that research activities were too fragmentary to be able to cope with the demand of sound soil conservation measures. Another recommendation was the use of pilot areas for a quantitative evaluation of accelerated erosion and the effects of new conservation measures in the water erosion prone areas of Mediterranean Europe. It was also suggested that the old projects should give way to more flexibility, so that programs could be modified during implementation to take advantage of experience gained and lessons learned. For an effective soil conservation policy for the Mediterranean region, the following are required:

- high level political pressure;
- proven technologies;
- clear financial incentives;
- a clear "stand alone" policy which could also be part of an environmental protection programme, or of an agricultural development programme;
- a suitable local organization to take responsibility for implementation.

Added to the above general requirements, two considerations should be taken into account:

- It is generally accepted that as little external intervention as possible is desirable, making the maximum use of existing social structures and institutions and existing farming practices, and minimizing the introduction of unfamiliar concepts or technologies.
- The use of subsidies should be avoided, where possible, because the programme is intended to be intrinsically attractive to farmers.
  Moreover, the conclusions and recommendations of the European Commission's Directorate General for Agriculture stressed the need for further research on the following topics:
- processes and mechanics of erosion;
- new methods for soil loss estimation;
- modelling soil erosion;
- new strategies for erosion control.

EC PROJECTS AND PROGRAMS FOR DROUGHT MITIGATION, LAND DEGRADATION AND DESERTIFICATION PREVENTION

In combating these problems, the EC in collaboration with other international organizations, have funded different projects and programs for mitigating drought, assessing soil erosion, preventing land degradation and desertification, and for providing useful information to design environmental policies (De Wrachien *et al*., 2002).

The most important of these projects and programs, are the following:

- ESD (European Soil Database)
- CORINE (COoRdination INformation Environment).
- MEDALUS (MEditerranean Desertification And Land USe).
- UNEP (United Nations Environmental Program).
- EFEDA (European Field Experiment in Desertification – threatened Areas).

The European Soil Database (ESD)

The European Soil Bureau (ESB) has been sponsoring the collection of soil information throughout the Mediterranean Basin in particular, and throughout Europe in general, for more than ten years (Montanarella *et al*., 1999). This has culminated in the compilation of the first version of an European Soil Database containing spatial data at 1:1,000,000 scale, harmonized for the whole continent, according to a standard international classification (FAO & UNESCO 1990), together with analytical data for standard profiles. The ESD, therefore, provides a starting point for delineating various aspects of soil erosion and land degradation at both the Mediterranean and the European levels (Jones, 2001).

COoRdination INformation Environment (CORINE)

The first project that has dealt with soil erosion and land degradation at the level of European Union (EU) was the “Soil Erosion Risk and Important Land Resources in the EU Mediterranean Countries” within the CORINE framework (Giordano, 1992). The project started in 1985 and finished in 1992. The project selected the topic of soil erosion because of its wide-reaching and serious effects on both land resources and the environment. From a practical point of view, the risk of soil erosion must be matched with the land evaluation. The methodology adopted was designed to satisfy the two points:

- the link between soil erosion risk and land quality;
- to separate between relatively stable factors (such as topography and soils) and those subjected to changes (such as vegetation and land use).

The outcomes of the project provided the users with a double set of information: the first was the potential soil erosion risk, which refers to a bare soil; the second set was linked to the actual soil erosion risk, and takes into consideration the existing land cover and use.

The proposed methodology should be considered as a set of guidelines and not a rigid scheme. The results obtained in the predictive approach should be considered appropriate for a given agro-climatologic zone.

Even if the project has to be considered as a first approximation, rather than a defined assessment of soil erosion risk and land quality, it does present the first genuine attempt to provide the information that the policy-makers need, to tackle the growing problems of soil erosion and land resources in the region.

MEditerranean Desertification And Land USe (MEDALUS)

In the 1990s the EU has promoted the project MEDALUS, with the aim of carrying out basic investigations on Mediterranean desertification by consolidating fundamental areas of research and by setting up models suited to predict climate change due to enhanced greenhouse effect, and quantify the land degradation and desertification processes (Brandt *et al.,* 1996)

The project was organized in four modules:

- Core field studies, for data collection to increase the understanding of basic processes and causes of land degradation and desertification in three main research areas of the semi-arid Mediterranean: Almeria (Spain), Sparta (Greece) and Sardinia (Italy).

The core program covered field measurements of different biotic and abiotic parameters under contrasting site conditions. Within this module a geo-referenced Data Base has been developed, containing not only the field data but also remotely sensed images.

- Developing land degradation models. This module has brought about the MEDRUSH land degradation model to assess and predict the desertification process.
- Application of the MEDRUSH model. This module has been implemented, especially, in the Guadalentin basin (Murcia, Spain) and in the Agri watershed (Basilicata, Italy), where the model has been tested and, subsequently, applied as a land management tool.
- Implementation of models to describe the present pattern and possible future trends of climate over the region, in order to assess the changing risk of desertification. Within this frame two approaches have been used. In the first, current trends in an indicator of atmospheric pressure (the height of the 500hPa surface) are extrapolated to around 2020, using a statistical model; the second approach uses the results from General Circulation Models (GCMs) to construct seasonal scenarios of the change, over time, in temperature, precipitation and potential evapotranspiration.

The MEDALUS project represents, perhaps, the most valuable compendium nowadays available of information concerning present pattern and future trends of climate, land degradation and desertification the Mediterranean region.

United Nations Environmental Program (UNEP)

The UNEP is not only concerned with the environmental issues of the Mediterranean region but also with the European issues as a whole (Giordano, 1993). Among the many UNEP contributions to the climate change and desertification is PAP/RAC (Priority Actions Program/Regional Activity Centre). The project consisted of two main subprojects: erosion mapping and erosion measurements.

The aim is to create a common methodology of erosion mapping in an area covering eighteen countries in the Mediterranean coastal zones. The project produced useful guidelines to help in:

- contributing to a better management of soils and other natural resources;
- designing measures for mitigating erosion processes;
- presenting a methodology and prerequisites for mapping and measurement of erosion processes;
- identifying preventive, protective and curative measures to mitigate drought and combat desertification.

European Field Experiment in Desertification-threatened Areas (EFEDA)

The aims of the previously described projects were to improve understanding of erosion and degradation processes to model desertification and its impacts, to predict future patterns of climate change and to identify and design possible mechanisms and measures for mitigating these effects.

The EFEDA project is mainly concerned with deforestation and was focused on the interaction between land surface and atmospheric processes. The field experiment was located in southwest Spain. It began in 1991 (Bolle *et al*., 1993) and included intensive campaigns of detailed measurements, from land, air and space, of surface characteristics and fluxes over three different type of land cover.

Although it is difficult to compare the above-outlined studies and results, as they have used different methodologies, they have the merit of providing new approaches and environmental policies to:

- assess, forecast and mitigate harmful impacts of droughts;
- better understand soil erosion, land degradation and desertification processes;
- identify preventive, protective and curative measures;
- address quantify and quality of natural resources in an integrated context;
- support innovation and participatory strategies;
- foster technology transfer and international co-operation
- provide an international forum for debating environmental issues and finding sound and sustainable solutions.

STRATEGIC ACTION PLAN (SAP)

The above-described themes, principles and project outcomes strike at the root of the major problems encountered in the process of desertification prevention and drought mitigation in the Mediterranean Basin. To implement their results, they have to be translated into actions through the formulation of programs which have to be based on consistent and standardized methodologies and take into account the actual conditions of the environment where they are expected to be implemented (Hamdy *et al*., 1999). These programs should be based on:

- adoption of a comprehensive approach that views land and water use and management and the environment in an integrated manner;
- promotion of regional co-operation to ensure that the concerns of all parties are considered in taking decisions;
- recognition of the linkages among soil erosion, land use and climate change;
- encouragement of a broad-base participation, including governments, professional and research Institutions and non-governmental organizations;
- endorsement of a phased program of actions at both international and national levels.

The objectives of SAP are to:

- evaluate trends;
- assess causes and implications;
- provide a cost estimate for investments;
- establish a framework for monitoring and evaluation;
- identify priority actions to address key issues.

Priority selection should:

- ensure selectivity, in order to concentrate resources on significant problems;
- avoid duplication and overlap;
- adopt flexible and cost effective solutions through adaptation and/or improvement of existing technology to specific tasks;

- select topic for investigation and research that are likely to realize the greatest benefit, considering return on investment, response time, probability of success and impact on agricultural production and other activities.

This integrated approach is expected to produce significant benefits in environmental and socio-economic terms, a more sustainable use of land and water resources and higher yields and incomes from agriculture, forestry and animal production.

CONCLUDING REMARKS

- The actual trend of soil erosion and land degradation in the European Mediterranean environment has recently become a serious problem. The consequences are not only related to the lost of soil fertility and land productivity, but also to salinization, acidification, contamination, compression, surface sealing, desertification, damage to life in soils and other negative impacts on human activities.
- Possible future climate change over the region, due to the global warming, are likely to lead to climate conditions characterized by a decrease in rainfall (drought) especially during the summer and subsequently leading to land degradation and desertification. In combating these problems, the EC in collaboration with other international organizations, have funded different projects for mitigating drought and assessing and preventing land degradation and desertification.
- In implementing the project results, the latter need to be translated into a Strategic Action Program. In doing so, one should concentrate resources on significant problems, avoid duplication and overlap and select topics for investigation that are likely to achieve the greatest benefit.
- Lessons learned and experience gained demonstrate that it is necessary to make a decisive break from past policies, to embrace a new holistic approach in land and water use and management, that is comprehensive, participatory and environmentally sustainable.
- Finally, to mitigate drought, combat land degradation and desertification and achieve a sustainable development, objectives and goals, policies and regulations, should be grounded in local realities, traditions and natural resource management strategies. The

environmental and socio-economic impacts of such policies and regulations should be assessed before implementation.

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PART IV

Regional Cooperation and Information Sharing

THE ENVIRONMENT AND SECURITY INITIATIVE: TRANSFORMING RISKS INTO OPPORTUNITIES FOR CO-OPERATION

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Environmental changes, increasing scarcity of natural resources or rising opportunities for rent-seeking behaviour, can play a *decisive* role in the emergence of conflicts – namely by accelerating or triggering social problems. Environmental stress rarely leads directly to conflict, but may cause tension in already marginalized areas. Land degradation and desertification with its implication for food security is commonly recognized as one such stress factor. As an added complication migration of affected people into cities or onto even more marginal land increases poverty and has the potential of causing social unrest and ethnic tension.

As environmental conflicts are closely linked not only to environmental stress but also to political and social structures, activities to abate threats need to include these socio-economic and political influencing factors. Foreign and security policy actors as well as environmental policy actors should be involved in the process. It is in acknowledging this multifaceted character of the issue at hand that three organisations with different mandates, expertise and networks joined together to form the OSCE/UNEP/UNDP Environment and Security (ENVSEC) initiative.

The ENVSEC initiative intends to provide a framework for co-operation on environmental issues across borders and promote peace and stability through environmental co-operation and sustainable development. It builds on the combined strength of the three lead organisations' expertise, experience and field presence. The project concept is designed to provide a coherent structure for three key areas of activity: vulnerability assessment and monitoring of environment and security linkages; capacity building and

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institutional development; and policy development, implementation and advocacy.

PUTTING ENVIRONMENTAL THREATS TO SECURITY ON THE MAP

In identifying potential threats to security the ENVSEC initiative works with a broad definition of "conflict," including under that term a continuum ranging from mere differences in the positions of actors, over sporadic use of violence, through to armed conflict. It would be too narrow to examine only violent conflicts, since the initiative is concerned as well with conflicts below the threshold of violent, armed struggles, which is where environmental conflicts are most commonly found. Furthermore, conflicts below the violence threshold offer a forum for cooperation and confidence-building. We suggest applying the term "conflict" to describe a situation in which severe social tensions and political disruption may occur and could result in the use of violence.

The initiative focuses principally on two sets of issues:

1. Environmental sources of stress between communities, regions or countries, in particular where these have the potential to undermine social and economic stability and lead to conflict.

2. Tools and approaches that can be used to bring about or strengthen cooperation and good governance between communities, regions and countries so that environmental problems are adequately addressed, social and economic stability is reinforced and conflict is avoided.

The ENVSEC initiative chose to adopt a regional approach in the belief that many potential sources of environmental conflicts can only be dealt with in their regional context, and that transborder co-operation on such issues can contribute to peace building particularly around scarce common goods. For example, in post conflict settings, joint efforts to clean up contaminated sites and restore natural spaces may revitalise both the environment and the trust among peoples and nations. Two pilot regions, Central Asia and south-eastern Europe were covered in the first phase, two more, south Caucasus and Eastern Europe, will be added in 2004.

The first phase of the initiative consisted of an assessment phase aiming at identifying the key environmental threats that might also have security implications. The assessment benefited from a series of regional and national consultations with local stakeholders, including representatives form government, civil society and academia. It also drew upon other sources and desk studies. A mapping team from UNEP GRID mapped out in graphical form the priorities identified in the initial assessment. The end product - compelling cartographic representations of the links between environment and security in these regions, with supporting text, and the network and shared vocabulary of its participants – were presented at the 5th Ministerial Forum “Environment for Europe” in Kiev and at the OSCE Economic Forum in Prague, both events took place in May 2003. The intention behind this somewhat simplified visualisation of risk factors in maps is to raise the awareness of the issues, put them higher up on the political agenda and provide a foundation in the regions concerned for further co-operative action and empowerment around environmental concerns. The effort also served to identify and reach agreement on key issues that would remedy further action and careful monitoring.

REGIONAL PRIORITIES

Soil degradation, salinization and desertification were identified as potential threats to security in the ENVSEC assessment phase. Other issues included water supply and contamination as well as industrial, municipal and hazardous waste. This type of environmental issues are typically classified as threats to human security, which links to national security by their potential for causing discontent, migration, unrest and destabilisation.

Although both pilot regions are affected, Central Asia presents the must urgency, with over 80% of its territory classified as dry, sub-humid, semi-arid and arid zones. The land area affected by desertification is significant, ranging from 66% in Kazakhstan to 97.7% in Tajikistan.

With the collapse of the Soviet system and agricultural subsidies, rapid increases in rural poverty have been ensued during the post-independence period. As poverty has been increasing, people’s options for pursuing livelihood diminished and as a result they were driven to seek quick returns from unsustainable practices, which lead to land degradation and reduce the lands carrying capacity to produce and provide its harvests. Considering that the majority of the population lives in rural areas, the impact of desertification and land degradation takes a high toll on their ability to survive.

Water logging and salinity present two major land quality problems in the region. In all five countries, maintenance of the water canals, drainage networks and irrigation schemes has been largely neglected in the 1990s. In Tajikistan, a mountainous country, irrigation in foothill zones induces groundwater recharge, intensifies water logging and salinization of the lower areas. In Uzbekistan, 50% of the irrigated land is considered to be saline, with high concentration up to 95% in downstream areas, especially in Karakalpakstan. These issues are linked to water scarcity and overexploitation of the existing resource.

As much as 90% of the regions crops are produced on irrigated land, with cotton as the dominating, and particularly thirsty crop. The focus on cotton as the main source of employment and foreign exchange has lead to mono-cultivation, which in turn further contributes to soil degradation and severely reduced bio diversity.

Toxic industrial waste has been dumped and buried extensively throughout the region, adversely affecting water, air and soil quality, in turn having wide health impacts on population and wildlife. The Semipalatinsk nuclear testing site in Kazakhstan, for example, hosted 470 tests between 1949 and 1989 resulting in radioactive fallout on an area as large as 300 000 sq km.

By diverting for irrigation four fifths of the water that was feeding that what used to be the worlds largest freshwater lake, the Aral Sea started shrinking. Between 1960 and 1998 the sea's volume declined with 80% and the Aral desert was formed. Uncovered sea and river beds are exposed to wind erosion and contaminated dust is carried over vast distances, affecting crops and causing respiratory diseases.

In other areas, for example in the mountains of Kyrgyzstan and Tajikistan, poverty and lack of income alternatives force local communities to engage in intensive cattle grazing, thus causing deforestation and erosion. Wood cutting for fire wood further exacerbates this problem and increase the probability of land slides.

ENVIRONMENTAL PRESSURES AND THE SOCIO-ECONOMIC FRAMEWORK

Environmental factors lead by no means directly to violent conflict; they are rather one strand within a complex web of causality in which are intertwined a series of socio-economic problems such as overpopulation, poverty, forced mass migration, refugee movements, hunger and starvation, political instability and ethno-political tensions. Environmental degradation and natural resource scarcity are both causes and outcomes of these socio-economic problems or are intensified by these.

Although unsustainable consumption and production patterns of richer nations may be a strongly contributing factor to negative environmental change, environmentally-induced conflicts arise mainly in underdeveloped regions with a lack of development policy alternatives, whose history makes them prone to conflict and where crises and conflicts are evidently an inherent part of their development.

Whether environmental stress indeed harbours conflict or leads to violence depends upon a series of socio-economic context variables, primary conflict factors and cognitive processes. These include cultural circumstances and traditions, ethno-political factors, civil society mechanisms of peaceful conflict resolution, the stability of the interior policy system and, finally, societal, institutional, economic and technological capabilities. It follows that, in addition to regulating consumption and ensuring an equitable distribution of renewable resources, the identified context variables offer points of leverage to prevent such environmentally-induced conflicts.

THE ROAD AHEAD

Despite the complexity of the sources of conflict, the environmental components provide a potential for preventive measures. Global environmental policy, in particular, relies on the principles of co-operation and reconciliation of interests. Using this experience, environmental policy instruments or negotiations on environmental problems can be used to resolve conflicts in which a peaceful solution to other, perhaps more decisive sources of conflict is not possible.

Within the framework of the ENVSEC programme, the partner organizations will develop regional, national and sub-national projects that strengthen social and institutional capacities to address threats to human security, triggered or accelerated by environmental stress. The Initiative is basically structured in three distinct but interlinked pillars, dealing with a) vulnerability assessment and monitoring, b) capacity building and institutional, and c) policy development and implementation.

Each of the pillars contains a variety of modules with specific project activities, which are not exclusive and can be added to at any point. The different modules strengthen each other and are best completed according to the comparative advantage and experience of the respective participating institution. Partners are encouraged to cooperate on each of the activities to increase inter-institutional cooperation, a key characteristic to this initiative designed to ensure a multifaceted view of a multifaceted problem, as described above. In the course of the project, participating organizations may add or select activities (either single projects or comprehensive programmes), which are appropriate to achieve the goals of this initiative and meeting the demand of the recipient region or country. Projects developed in the framework of the Environment and Security Initiative will meet the following criteria:

- Foster sustainable development or environmental cooperation as a component of conflict prevention or peace development;
- Be conceptualized and implemented in cooperation with local partners and preferably involve more than one of the Initiative's lead agencies;
- Address issues and needs revealed in the assessment exercise (i.e. identified by stakeholders, national action plans, existing processes and endogenous capacities) and preferably have component related to both the capacity building/institutional development and policy development/implementation spheres.

Vulnerability assessment and monitoring

Within the first phase of ENVSEC maps and case analysis were used to communicate areas of concerns (or hot spots) to policy makers and stakeholders in civil society. The two case study regions were south-east Europe and Central Asia. In the next phase over the following three years, the assessment methodology and process needs to be evaluated against the background of other assessment projects and the ENVSEC brochures' reception by policy makers and experts. The refined assessment methodology will be transferred to two other regions during 2004, namely the Caucasus and Western NIS. An initial workshop for this purpose has already taken place in the Caucasus in November 2003.

It may also prove to be necessary to focus on specific countries, which are most prone to security implications of environmental stress or require particular attention with regard to fostering transboundary environmental cooperation. Finally, concentrated efforts will focus on specific regional, national or local hot-spots, which deserve special attention, such as the Aral Sea and region, the Ferghana Valley, Aktau and neighbourhood, and the Axe Tselinny-Semei-Oksemen.

Vulnerability assessment, development of appropriate indicators, setting up of an integrated database and the establishment of a long-term monitoring system are to be facilitated and promoted. Regional stakeholder dialogues will initially concentrate on information sharing, data exchange, knowledge networking and indicators for early warning. The monitoring system will also allow us to monitor progress of the initiative and environmental threats to security addressed.

Capacity Building and Institutional development

The vulnerability of an economy or a state as a whole to environmental stress depends strongly upon its institutional capabilities - whether or not there are appropriate environmental policy institutions at the national, regional and local levels, such as a functioning environmental administration, legal and economic instruments by which to regulate resource consumption and a monitoring system. It is also a matter of the potential for creating economic alternatives for developing societies, the ability to engage in long-term planning processes, the ability to adopt strategic policies and the integration of state and non-state resources and capabilities.

The initial assessment phase allows the ENVSEC team to identify areas where immediate or long term assistance is needed in terms of capacity building and institutional development. The focus of the ENVSEC initiative in this pillar is to address existing needs and gaps in the ability of the countries to fulfil their commitments, be they under global environmental agreements or national action plans.

On the governmental side, strengthening the capacity of institutions particularly to develop and negotiate appropriate mandates and modus operandi as well as appropriate legal and policy frameworks is a key priority. Equally important is the strengthening of civil society as crucial capacity to foster democratic participation, social mobilization and information dissemination, amongst other, in environment and security issues.

One activity already underway under the ENVSEC umbrella and also contributing to the implementation of the second component of Objective 6 of the EECCA strategy is a programme on “Awareness Raising and Public Participation in Decision-Making through Improved Access to

Information and Environmental Education". The programme is aimed to assist in provision of high quality updated information to environmental decision-makers and stakeholders, promotion of public participation and environmental education by supporting environmental journalism and media and strengthening mechanisms for exchange of environmental information between government agencies and the general public.

Policy Development and Implementation

Raising awareness for environment and security linkages and agreeing on areas for further environmental cooperation are at the centre of the ENVSEC initiative. Relevant conclusions and recommendations may be put forward on the international agenda to promote integrated assessment methodologies, inter-institutional cooperation and policy integration. Integrated assessments need to become part of the existing frameworks of multilateral environmental agreements, such as the UN Framework Convention on Climate Change, UN Convention on Combating Desertification and Convention on Biological Diversity. The ENVSEC initiative aims to cooperate and exchange experiences with other initiatives, such as the National Capacity Self-Assessments (NCSAs) supported by the Global Environmental Facility (GEF), and organizations such as UN ECE, OECD (DAC), EU and NATO, who are invited to join the ENVSEC programme or pick up or add special modules.

One of the major shortcomings in integrating environmental concerns in conflict prevention and mediation efforts (and vice versa), is the lack of transfer of knowledge and institutional policy learning. This basically refers also to the problem of integrating general findings on transboundary environmental cooperation and peace promotion measures into multilateral and bilateral donor activities. The Environment and Security Initiative will help to transfer these general findings to the policy development of donor agencies and their projects.

Policy integration is a major challenge to develop a coherent governance structure, which allows addressing the environment and security linkages. Several donor activities in these regions in the past have demonstrated the need to promoted and support policy integration through provisions and mechanisms for risk/conflict assessment into national development plans, multilateral environmental agreements (such as UNECE environmental conventions or UNFCC, CBD) as well as strategic environmental assessments, sustainability impact assessment, national and regional environmental policy programmes, and sectoral strategies (public health, agriculture). On the other hand sustainable resource management practices and transboundary environmental cooperation efforts need to be integrated in conflict prevention and peace building strategies, peace and conflict impact assessments and conflict prevention strategies.

CONCLUSION

The ENVSEC initiative is characterized by:

- three international institutions cooperating in a long term effort, with a view towards other agencies joining this Initiative;
- reaching beyond purely academic exercises and consulting with stakeholders in the region on the results of our analysis, both from government and civil society, creating credibility and ownership of the Initiative;
- overcoming disciplinary borders and integrating environmental, economic, social, security and institutional aspects;
- combining analytical, cartographical and communication skills to address policy makers at various levels; and
- fostering the development and practical implementation of policies that seek to comprehensively address environment and security linkages in vulnerable regions.

The ENVSEC initiative could be used as a model of cooperation that could be replicated elsewhere. A successful replication of the initiative would require that the right combination of partner organizations could be convened for the effort. A key feature of the ENVSEC initiative is precisely the close cooperation between three international organizations whose particular mandates ensure that security, environmental and social issues are all taken into account.

Fostering networking and exchange of information in the Mediterranean region: The MEDCOASTLAND Thematic Network[1]

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ABSTRACT

Land degradation and desertification represents one of the most striking sets of processes affecting the Mediterranean Region causing persistent deterioration of the physical, chemical and biological properties of the land components, especially the soil. Land degradation, then, results in loss of overall *productivity*, which in turn impairs sustainable development. This is particularly evident in the Southern Mediterranean, with entire landscapes no longer able to maintain their productive functions.

Although many EU-funded research projects have succeeded in collecting information and understanding physical processes of land degradation, their impact on the territory has been rather poor partly due to the still existing communication gaps between institutions/scientists and land users. The lack of networking among different Mediterranean countries and the lack of integration between physically driven and income-product generating criteria are proving to further aggravate the situation.

In addition, a real participatory approach involving scientists, decision-makers, and local communities is still missing. In order to fill these gaps and to foster exchange of information in the region through the establishment of a task force involved in combating land degradation, the MEDCOASTLAND Thematic Network was set up. The main objective of the Network is to contribute to the sustainable development, planning and management of natural resources in the Mediterranean through dissemination of existing research results derived from previous projects. The dissemination is done via the Internet, five workshops, and one international conference. These events will be organised over the period 2002-2006.

There are 13 countries (from south Europe, North Africa, Middle and Near East) participating in the Network making a total of 36 partners, of whom 18 are research and educational institutions, 9 represent decision makers and the remaining 9 partners are farmers associations and/or non governmental organisations (NGOs). The International Centre for

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Advanced Mediterranean Agronomic Studies (CIHEAM) through the Mediterranean Agronomic Institute of Bari, in Italy is coordinating the project.

The project will address not only the physical aspects of land degradation. Specific Work Packages deal with income-generating aspects of soil conservation, including socio-economic considerations; detailed analyses of participatory approaches (top-down and bottom-up) involving decision-makers and local farming communities; development of national and regional guidelines to promote sustainable land management; and finally setting up the floor for continued cooperation in the region, even after the life span of the project. Additional information is available at the web page of the project: http://medcoastland.iamb.it. The MEDCOASTLAND web site provides also important links with other projects where similar activities are taking place (*i.e.* LADA, SCAPE).

BACKGROUND INFORMATION

Under section A3, priority "d" Regional Environmental Sustainability the International Cooperation Programme in the Mediterranean (INCO-MED) of the European Commission (EC) calls for research and actions in support of integrated policy and resource management of Mediterranean coastal zones. More specifically, priority "d" lists within the specific objectives "the sustainable development of coastal areas and the impact of human activities on natural resources (particularly ground resources like water) as a priority for 2001 calls, stressing research needs (among others) for maximised planning and management of coastal areas through the development of participatory strategic approaches".

Many specific objectives of priority "d" are integrated within land degradation in coastal zones. In a broader meaning the concept of land includes soil, water and the biological production potential of the earth's surface. Consequently, the degradation of natural resources is expressed through the loss of productivity, influenced by a set of factors most notably represented by soil erosion, salinisation, impact of groundwater withdrawal, vulnerability to flooding, land abandonment, soil sealing and prime land loss due to urbanisation.

Land degradation is further accelerated by the non-sustained human-induced actions such as the inappropriate agriculture activities, and the overuse or misuse of natural resources aggravated by socio-economic constraints (Ghazi, 1996). As already highlighted by many researchers, human induced degradation processes especially in the coastal areas are often related to lack of land use planning (Leontidou, *et al,* 1998). This is mainly due to insufficiently informed decision makers and scarce participation of rural communities in a context where rapid economic growth and tourism development make it urgent to improve the land management system.

The integrated management of the factors included in the natural ecosystem represents one of the most effective ways to contribute not only to land conservation management but also to achieve environmental sustainability (Kapur, *et al,* 1999).

The enhancement of environmental sustainability is increasingly pursued at European level as a strategy that should be developed also across the Euro-Mediterranean region (including south Mediterranean countries). Among others, environmental sustainability includes the conservation of natural resources (maintaining and enhancing soil fertility, soil structure, organic matter content, ground and surface water quality and quantity) and avoidance of soil pollution through a more efficient use of non-renewable natural resources.

Land degradation represents one of the aspects that deeply constrain the sustainable development of coastal areas of the Mediterranean (Zdruli *et al,* 2004). Often land and soil degradation is due to misuse or miss-management of natural resources including soil, water, biodiversity and vegetation cover (Conacher A. and Sala. M. 1998). Moreover, there is a chain reaction between the degradation of land resources located in inland regions of specific catchment areas that causes problems to the coastal zones. Deforestation and forest fires, along with overgrazing accelerate soil erosion and surface water runoff and increase therefore flooding intensity in the lower plains. All of this calls upon the need of formulating indicators, warnings and actions to control the equilibrium between coastal areas and inland regions.

Good agricultural practices including the improvement of land and soil conservation methods contribute widely to natural resource management in the Mediterranean areas. Agriculture still remain one of the major driving forces in the South Mediterranean countries, contributing to more than 50% of the gross income of these countries (Hamdi H. and Abdelhafez S., 1999).

Moreover, today the patterns of land-use in the Mediterranean coastal zones no longer reflect the long established practices of a traditional rural agriculture (UNEP / MAP / PAP, 1995; Pleinevaux C., 1996,). Instead, they result more and more from the multiple decisions of land users concerned for the expected financial returns of different crops, fruit trees and livestock and of decision makers dealing with industrial and commercial companies, as well as with urban development and infrastructure expansion expressed in construction of motorways and tourist holiday centres.

In many Mediterranean coastal areas the fragile ecosystem continues to degrade (Zdruli, *et al,* 2004). Land degradation and desertification therefore, represent some of the most evident processes in the region, involving deterioration of soil, water quality and losses of productivity (Thornes, 1998). All this is taking place despite the political recognition of the problems and the existence of policy instruments (Pleinevaux C., 1996). The main causes of coastal area degradation are related however to human activities i.e. urbanisation, agriculture production, and industrial and tourism development.

Despite the great role of humans in accelerating land degradation, the process is, nevertheless significantly amplified by physical factors such as climate, topography, soil erodibility and local vegetation status (Perez F.-Trejo, 1992; Yassoglou, 1998). Human communities in their role as hunters, fishermen, and farmers have over the centuries structured and restructured the physical environment. Within the South Mediterranean, the evidence of degradation is clear, with entire landscapes no longer able to sustain cultivation.

Over the last 20 years The European Commission has funded many projects and there is a significant number of environmental and socio-economic data and information gathered on the management of Mediterranean natural resources. Other international donors as well as local institutions have also funded research on land management including the topic of land degradation and desertification (MEDCOASTLAND database, 2004). Research has produced many results that still need proper horizontal spreading and the backing of relevant decision makers and land users on both shores of the Mediterranean before it can be effective and produce the required results.

In the early nineties the EC recognised the urgency and importance of the increasingly land degradation and desertification problem in the European Mediterranean, by initiating in 1996 research projects like EFEDA and MEDALUS (Mairota, *et al,* 1998), and by establishing since 1989 a research programme named “EPOCH” to investigate causes, impacts and management implications of land degradation using an integrated and interdisciplinary approach.

Co-ordinated research of high standards, involving soil, water, climate, human activities, has been performed by many other EU funded projects like MEDALUS II and III, CORINE, RESMANMED, ARCHAEOMEDES, DEMON, and MODMED, just to mention some of them.

THE MEDCOASTLAND APPROACH

The above-mentioned EU funded research projects (as well as many others) have made good achievements in collecting information and understanding physical and socio economic processes of land degradation and desertification. However, their impact on the territory has been very poor partly due to i-) communication gaps still existing among institutions / scientists and local communities within the country and the region; ii-) lack of networking among different Mediterranean countries to enhance regional soil conservation and sustainable land management; iii-) lack of integration between physically driven criteria and income-product generating criteria, with particular regard to agriculture productivity and consequently to farming communities.

In many publications related to land degradation, environmental and socio-economic factors have been studied in great detail with the attempt of providing a frame for integrated coastal management (MEDCOASTLAND database, 2004). Nevertheless, research and studies carried out by institutions and research centres especially of the South Mediterranean countries are still fragmented and scattered and often respond to local and isolated interests rather than regional ones.

Existing national governmental structures as well as international institutions involved in the region have a great role to play towards the promotion of sustainable development and environmental protection of the natural resources. However, their involvement is often fragmented and the lack of a real participatory approach with the joint involvement of scientists, decision makers, and local communities is still lacking behind (Oblitas and Raymond 1999; Groenfeld and Svendsen, 2000).

It is for these reasons that in December 1999 at the premises of the Mediterranean Agronomic Institute in Bari, Italy, the European Commission, the Italian Ministry of Agricultural Policies and the International Centre for Advanced Mediterranean Agronomic Studies organised a first meeting to establish the Euro-Mediterranean Soil Information System Network. The meeting was concluded with the signing of a Memorandum of Understanding (Zdruli *et a.,* 2001) between thirteen Mediterranean countries that paved the way to form latter the MEDCOASTLAND thematic network.

The good start of Bari meeting was followed by two regional workshops, one held in Lebanon in January 2001 and another in Morocco in July 2001. It is worth mentioning that along with CIHEAM, also the European Soil Bureau, based at Institute for Environment and Sustainability of the Joint Research Centre of the EC in Ispra, Italy and the Institut National de la Recherche Agronomique (INRA), Unite INFOSOL located in Orleans, France have contributed to this establishment. Especially INRA deserves credit for preparing the Instructions Guide for Elaboration of the Soil Geographical Database for the Eurasia and Mediterranean at 1:1,000,000 scale (Lambert *et al,* 2002), that in fact is an extension of the Soil Geographical Database of Europe (1:1 M scale) into the Mediterranean Region.

Another important event held in Bari, Italy, in September 2001 was the 7th International Meeting on Soils with Mediterranean Type of Climate (7th IMSMTC) that brought again together soil scientists, agronomists and environmentalists from more than 25 countries and enhanced further on the links among the Mediterranean people (Zdruli, *et al,* 2003).

The major goal the MEDCOASTLAND Thematic Network is to enhance long-term collaboration and co-operation in the Mediterranean in order to address the sustainable use and management of natural resources and assist in developing appropriate land use policies. Hopefully, this will be also formalised at the end of the project with the signature of an Agreement of long-term co-operation among all countries included in the project.

Various organisations have experienced in the past several difficulties and constrains when trying to link different countries together, therefore putting together such a Mediterranean-wide network and facilitate partner's participation is not an easy task. For cultural, historical, and many other reasons, institutional partners, especially from Southern Mediterranean countries are often in conflict with each other or reluctant to share data and information. Therefore, the establishment of MEDCOASTLAND in a certain way is an important milestone for the region.

Another relevant "not-solved" problem concerns the temporal scale of processes involved in land and soil degradation especially in the coastal zones. The temporal scale is much longer than the time span of any single programme or action aiming at mitigating landscape and soil degradation (S.E. van der Leeuw – 1996). With its long-term philosophy MEDCOASTLAND will try to address land degradation and mitigate its impacts even after the project is over.

All players involved in the fight against land degradation and desertification face difficulties that require a multidiscipline and participatory approach. Previous funding has not permitted strong and effective dissemination and increased awareness in the Mediterranean countries in regard to land and soil management. Thus, this thematic network that brings together researchers, decision makers and various categories of farmers, environmentalists, and NGOs is the perfect place to share ideas and information.

Objectives of the project

The objectives of MEDCOASTLAND can be summarized as follows:

- Implement effective co-ordination and dissemination of research studies and projects dealing with land degradation and soil conservation in the Mediterranean region and allow access to easy-to-use information;
- Assist in planning and management of natural resources, particularly in the Mediterranean coastal areas, with special emphasis to land degradation assessment and resource base conservation and management;
- Establish a Mediterranean-wide permanent communication structure between researchers, decision makers, land users and non-profit organisations involved in combating land degradation;
- Identify major gaps in information and knowledge-base to reach a proper regional understanding of sustainable land management;
- Formulating an ecosystem-based assistance methodology for land users;
- Developing an income-product generating approach in soil conservation management;
- Promoting participatory management of the land system;
- Drafting appropriate policies and guidelines to support sustainable land management in the Mediterranean Region
- Link research activities and future needs with actual concerns;
- Provide a framework to assist regional planning and EU-funding in the Mediterranean areas.

Partners of the Network

The MEDCOASTLAND Thematic Network groups together 36 partners from 13 countries of the Mediterranean region (Fig. 1 and 2). They represent 18 research and educational institutions, 9 decision makers and 9 farmer associations and NGOs. The European countries are represented only by research, educational or decision maker partners, while almost all other countries have a full representation at all three levels.

From the operational point of view there are differences among partners in regard to the distribution of tasks, however, an active participation from all members is encouraged without regard to professionalism or hierarchical position in governmental, private or public administration. The network is based on the concepts of "*equality*" and "*free exchange of ideas and information*," always following the objectives of the project. In addition, there is also a Steering Committee that was established during the Kick-off Meeting. Its main duty is to control and supervise completion of objectives of the project and the performance of partners.

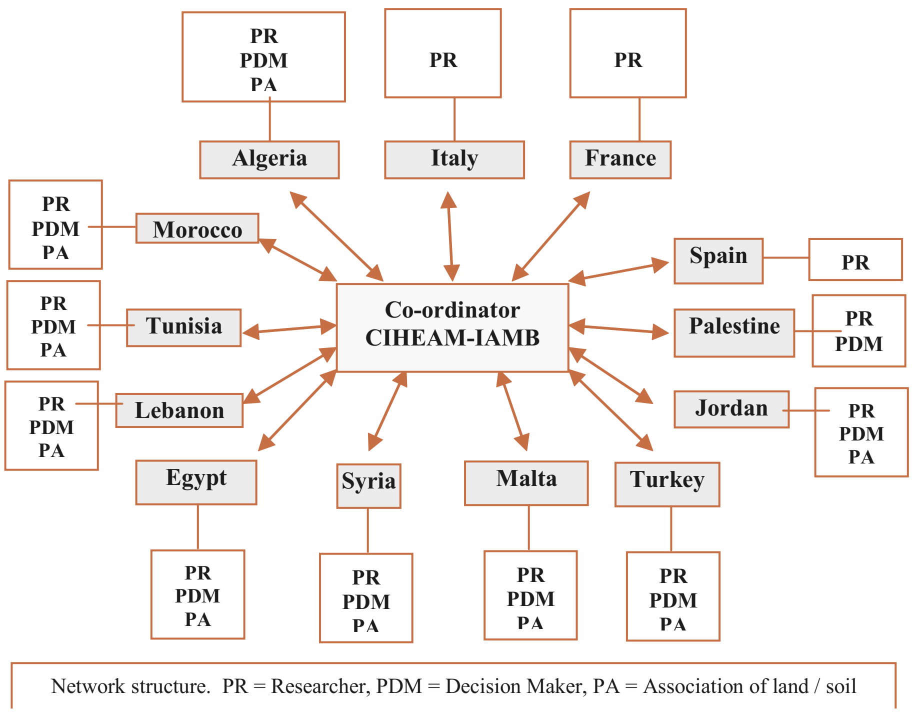

Figure 1. Countries included in the Network

Table 1. Partners of the MEDCOASTLAND Thematic Network

Partner n°	Institution	Country
P1	CHIEAM – IAMB	ITALY
P2	Institut National Agronomique	ALGERIA
P3	Alexandria University, Faculty of Agriculture	EGYPT
P4	Ministry of Agriculture	JORDAN
P5	National Council for Scientific Research	LEBANON
P6	Ministry for Agriculture and Fisheries	MALTA
P7	Ministere de l'Agriculture, Direction des Sols	TUNISIA
P8	Ministry of Agriculture	PALESTINE
P9	Ministry of Agriculture and Agrarian Reform	SYRIA
P10	Institut Agronomique et Veterinarie Hassan II, Soil Science Department	MOROCCO
P11	University of Çukurova, Faculty of Agriculture-	TURKEY
P12	Ministrere de l'Agriculture	ALGERIA
P13	The National Authority for Remote Sensing & Space Sciences	EGYPT
P14	University of Jordan, Faculty of Agriculture,	JORDAN
P15	Ministry of Environment	LEBANON
P16	University of Malta, Institute of Agriculture,	MALTA
P17	Institut National Agronomique de Tunisia	TUNISIA
P18	Land Research Center	PALESTINE
P19	University of Tishreen	SYRIA
P20	Ministere de l'Agriculture du developpement Rural et Eaux et Foret	MOROCCO
P21	General Directorate of Rural Services	TURKEY
P22	Groupement de Mise en Valeur Salmastre	ALGERIA
P23	Halazen Development Association	EGYPT
P24	The Jordanian Society for Desertification Control & Badia Development	JORDAN
P25	Agricultural Cooperative Association	LEBANON
P26	Farmers Central Co-operative Society, Ltd	MALTA
P27	Parcelle El Oueslati	TUNISIA
P28	The General Union of Peasants	SYRIA
P29	Ecole Nationale d'Agriculture de Meknes	MOROCCO
P30	Village Committee/Assoc. Product. Oliv. Nakhla Watershed	MOROCCO
P31	Adana Farmers Association	TURKEY
P32	Institut National de la Recherche Agronomique	FRANCE
P33	Consejo Superior de Investigaciones Cientificas	SPAIN
P34	Nucleo di Ricerca sulla Desertificazione., Università di Sassari	ITALY
P35	European Commission – General Directorate JRC-IES-ESB	ITALY
P36	Arab Center for the Studies of Arid Zones and Dry Lands – League of Arab States	SYRIA

The project will have duration of 4 years (2002-2006). It was launched in October 2002 with the Kick-off meeting held at the Mediterranean Agronomic Institute in Bari, Italy. The photo below shows the participants of this event.

Figure 2 . Participants of the Kick-Off Meeting held in Bari in October 2002

Description of Work Packages

The project breaks down into seven Work Packages (WP) that are logically linked with each other and follow a sequence of events.

WP1 deals with the *dissemination and sharing* of data, information and knowledge through an Internet-based communication, as well as with the *activation* of a permanent WEB-Forum on *Land Degradation*. The whole communication platform takes the configuration of a *Virtual Campus.*

WP2 focuses on the environmental factors influencing land degradation and the identification/application of appropriate indicators to assess and monitor land degradation, in order to develop an *ecosystem-based assistance* to land users and owners for achieving land conservation management. (Work Package Leader: Prof. Dr. Selim Kapur, University of Çukurova, Adana, Turkey).

WP3 investigates the experiences of *soil conservation management practices* suited also to generate *income*. Economically driven solutions that may lead to mitigation or reduction of soil degradation processes are highlighted. (Work Package Leader: Prof. Mohamed Badraoui, Institute of Agronomy and Veterinary Sciences, Rabat, Morocco).

WP4 aims at promoting *participatory management* of the land system, analysing bottom-up and top-down decision-making, decentralization, and other social and organizational structures of the participatory approach. (Work Package Leader: Prof. Dr. Fawzi Abdel Kader, University of Alexandria, Alexandria, Egypt).

WP5 works out the existing policies of the partner countries to abstract *National* and *Regional Guidelines* for a more effective adoption and implementation of land conservation management. (Work Package Leader: Dr. Talal Darwish, National Council for Scientific Research, National Centre for Remote Sensing, Beirut, Lebanon).

WP6 elaborates and tends towards the signature of a *draft agreement* among participating countries on *data share* and *long-term cooperation* for a joint effort to promote land conservation management at the Regional scale. (Work Package Leader: Drs. Sonya Sammut, Ministry for Rural Affairs and the Environment, Malta).

WP7 covers all the activities related to *information retrieval* needed to satisfy the requirements of all other work packages.

Figure 3 provides the schematic structure and several links between the work packages.

For the whole duration of the project a series of five workshops and one international conference will be held. The first workshop was successfully held (Zdruli *et al,* 2004) in Adana, Turkey in June 2003. This will be followed by four other workshops to be held in Marrakech, Morocco in February 2004, Alexandria, Egypt, October 2004, Beirut, Lebanon, April 2005, and Marsa, Malta in November 2005. The international conference will be held in Bari, Italy in June 2006 and will finalise the results of the project.

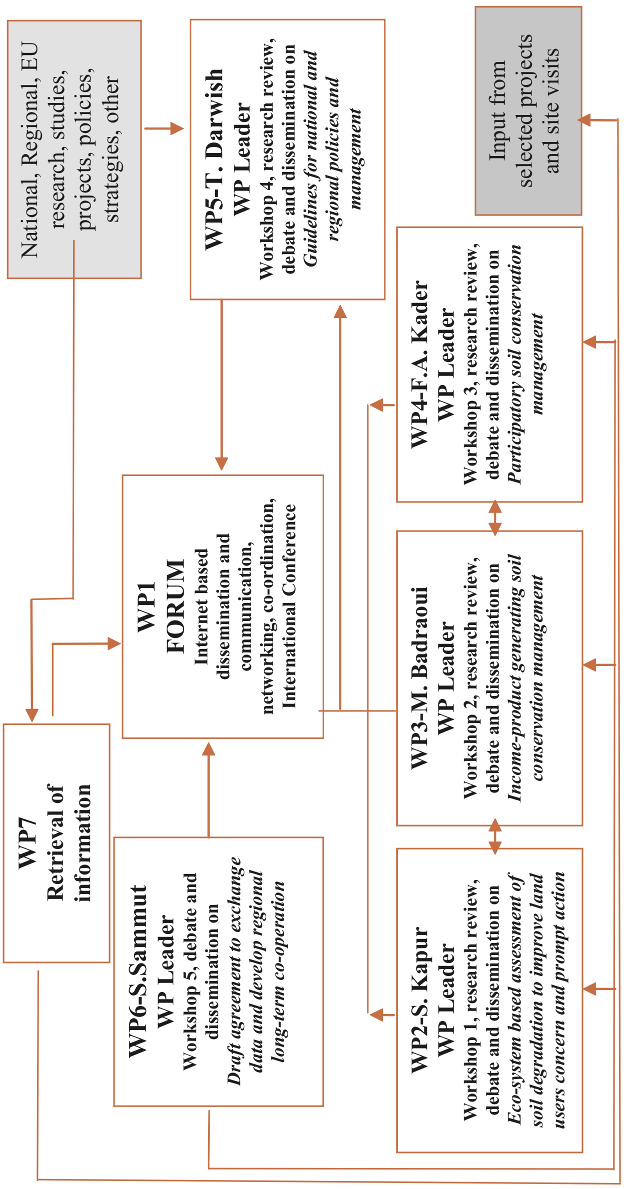

Figure 3. Structure and links among Work Packages

UP-TO-DATE RESULTS AND FINDINGS

Obviously, much of the work so far[49] has been concentrated in the WP1, WP2, and WP7. However, all other Work Packages have received the necessary attention. Following are some of the milestone achievements of the first year of the project.

In the context of **WP1** specific tasks addressed during the first year include:

i-) Elaboration, structuring and organisation of the web page http://medcoastland.iamb.it. For the period January 2003-January 2004 more than 4,100 people visited the web page;
ii-) Activation of the internet FORUM on land degradation;
iii-) Establishment and implementation of the database;
iv) Promotion and maintenance of the database. As of 31 January 2004 there are already more than 1,600 files of information retrieval downloaded into the database;
v-) Preparation and dissemination of two six-monthly newsletters;
vi-) Preparation of project's brochure;

Activities of WP2 reached their highest level with the organisation of the Workshop held in Adana, Turkey at the premises of the University of Çukurova in 2-7 June 2003. The theme of the workshop was "*Ecosystem-based assessment of soil degradation to facilitate land users' and land owners' prompt actions*". The main research focused here is land and soil degradation as seen not only in terms of natural factors (water, climate, topography, geology, soils, vegetation), influencing the process, but also in terms of human-induced land degradation. Intense discussions, on the Driving forces, Pressures, State, Impact, Response (DPSIR) framework (Blum 2001) as well as on other related subjects were addressed during the workshop and will be thoroughly consulted during lifetime of the project.

The thematic area of WP2 also involves the assessment of interactions between land degradation in coastal areas and physical and non-physical processes such as: soil erosion, salinisation, overgrazing, soil sealing and urbanisation, soil resilience and soil quality, desertification, and the practical use of the DPSIR framework. The MEDCOASTLAND Thematic Network is formulating and proposing indicators for land conservation, which could be assessed in terms of economic and production needs of the land users. The socio-economic aspects will be better addressed

[49] Refers to December 2003

in the next workshop to be held in Marrakech Morocco, in February 2004 in the context of the activities of the Work Package 3.

The experience accumulated up to now shows that extensive scientific research has been carried out in the Mediterranean Region especially over the last 20 years. The international and local organisations have invested heavily in several issues related to land degradation, desertification, and conservation management and have already spent millions of dollars in these activities (MEDCOASTLAND database 2004).

A direct positive impact of such investment among others is the creation and enhancement, of highly qualified human resources spread throughout the Mediterranean region. In fact there is an incredible wealth of highly trained professionals working in local and international organisations in many participating countries of the MEDCOASTLAND Network. This becomes more appreciated if one should notice that North African and Middle Eastern countries take a great share of this wealth.

Why land degradation still remains such a great threat to natural resources in the Region is an important question that MEDCOASTLAND asks. A detailed analysis of the findings of MEDCOASTLAND shows that retrieving *real results and data* is often difficult, as authors of previous research projects either are reluctant to provide them or these results were never made public for several reasons. The same is valid if the financial contribution or the budget of the project is required. Whenever possible, *communication and dissemination of research results and/or projects (when available) are rather poor* and in consequence, there is repetition of the same or similar subject matters even within the same country.

Another gap is the fact that often *the link between qualified professionals/scientists and decision or policy makers is weak or missing*. Often decision makers are not informed of what scientists and researchers are doing, and moreover very little are known by the farmers or land users who bear the real effects and the burden of land degradation that is still menacing the limited land resources of the region.

The general understanding is that *rural communities alone could not afford the price of land degradation and desertification*. A societal and international commitment is necessary to face these problems. The MEDCOASTLAND project will try to play its role in increasing public awareness on both shores of the Mediterranean and assist in disseminating positive results in the fight against degradation of natural resources for the pursue of the long and difficult road of sustainable development. In a simplified way this means to avoid previous mistakes and to learn from positive past experiences.

Responsible persons

Cosimo Lacirignola, *IAMB Director;* Dirk Pottier, *EC Scientific Officer;* Giuliana Trisorio Liuzzi, *Coordinator;* Pandi Zdruli, *Project Manager.*

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DESERTIFICATION IN THE ARID AND SEMIARID MEDITERRANEAN REGIONS. A FOOD SECURITY ISSUE

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ABSTRACT

The distinctive character of Mediterranean areas arises from both physiographic conditions and the history of human development. The aridity, the frequency of drought events, the management of natural resources, especially soil, water and vegetation cover and the human pressure on fragile ecosystems, have produced land degradation, water shortage and. Finally, high risk of desertification, all issues increased by the effects of the climatic change. On the other hand, the already existing food security problems, especially in South Mediterranean countries, can be increased because of these issues. . In this work we make a description of desertification processes in the Mediterranean area and we relate them to food security issues since we consider they are closely connected. Differences between North and South Mediterranean approaches to desertification and food security are marked and a special focus on causes for food insecurity is presented. Poverty, especially rural poverty, is considered the main driving force for food insecurity and possible solutions are discussed. Aspects like small farming, land tenure, local markets, trade aspects and water issues are considered relevant. Support to small farmers and local markets is considered essential to assure food security and to stop desertification processes. Finally, reforms on land and trade policies are considered necessaries.

***Desertification in the Mediterranean Region*: *a Security Issue*, 401–428.**
William G. Kepner, Jose L. Rubio, David A. Mouat & Fausto Pedrazzini, eds.

INTRODUCTION

Desertification is a land degradation problem of major importance in the dry regions of the world. At the same time, desertification has become a major environmental issue in scientific, technical, political and even the popular circles. A definition of desertification should recognise that it is a land degradation process that involves a continuum of change, from slight to severe degradation of the ecosystems, especially the plant and soil resources, and is due to human activities. The United Nations Convention to Combat Desertification defines desertification as "Degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 1994)).

Desertification expresses the result of combination of geographical, climatic and socioeconomic conditions, and natural resources management, especially for farming activities and rural development (López-Bermúdez, 2002; Kosmas *et al*., 2002), expressed at different spatial and temporal levels (Ibáñez *et al*., 1997; García-Ruiz *et al.*, 1996). It is the synergetic action of climatic conditions at different levels that are amplified by means of human action (Scoging, 1991; Thomas & Middleton, 1994; López Bermúdez, 1996a).

Desertification process means undercapitalization of the environment since it reduces the soil productivity levels which, under climatic conditions including negative water balance, have been weakened by inappropriate basic natural resources management. Human being accelerates desertification in the existing arid climatic conditions and drought (Puigdefábregas, 1995; López Bermúdez, 2002).

Nowadays, desertification is a complex issue forming a part of a global change system, with strong interrelations between causes and consequences. Inn order to understand desertification, it is necessary to know the natural environment, the structure, dynamics, evolution and vulnerability of the affected areas, and the history of the resource exploitation systems. Desertification can be considered as the most significant threat to the environment in Mediterranean areas, especially in southern Mediterranean countries. In many areas of these countries desertification is closely connected to problems in food security, defined as the chance of access for everybody and every time to enough food supply for a healthy and active live. While more and more resources are needed in these areas, desertification threatens the availability of productive land. Potential climatic change effects can increase the problem and risk food security for millions of people.

VULNERABILITY OF MEDITERRANEAN REGION TO DESERTIFICATION

The Mediterranean climate, with the scarcity, inter-annual variability and intense precipitations and the high summer temperatures, produce the most eminent feature: the aridity. The annual rainfall varies from about 1000 mm in the northern areas, to 200 mm and less in the southern drylands. In General, the rainfall has decreased since the end of the last century, though the eastern and western parts of the Mediterranean tend to behave somewhat differently (Conte & Guifredda, 1991). The Mediterranean landscapes are polygenetic, showing various generations of landforms and processes, many of which are Pleistocene and terminal Miocene relics (Bradbury, 1981; Di Castri 1981).

The history of land degradation in the Mediterranean region is very long and it has been extensively studied in many countries (Brandt & Thornes 1996; Rubio & Calvo, 1996; Van Der Leeuw, 1996; Groves & Rackham, 2001). The impact of human activities on Mediterranean land (agriculture, deforestation, overgrazing, forest fires, etc.) has developed the landscape, starting an anthropogenic erosion epicycle, and hillside denudations was worsened in the Mediterranean Basin with the coming of classical civilizations (Butzer, 1974). The destructive effects of human action on the natural ecosystems in the Mediterranean Region began at local scales during the Neolithic Age, covered large areas during the Roman Time and continue to the present (Yassoglou, 2000).

In the Mediterranean Region, land degradation advanced to the state of desertification, following a localized pattern, during periods when climatic aridity and excessive human pressure coincided (López-Bermúdez, 1996b, 1997). However, it was the technological development, the industrialization of agriculture, the exploitation of marginal land, forest fires, and urban sprawl on fertile soils the responsible for the increase in the rate of land degradation during the last 50 years. Currently the Mediterranean Region, in spite of the high diversity of their ecosystems, is extremely fragile and, therefore, potential changes due to climatic and human causes may drive to desertification. Mediterranean countries share a lot of problems, such as rainfall seasonality, depopulation of rural areas, urban sprawl in the most fertile soils and coastal areas, decrease of crop productivity, natural disaster recurrence, soil erosion, biodiversity loss and, finally, the risk of desertification, but important socioeconomic differences among all the countries, where development, participation and educational and political processes vary, inhibit common approaches and programs designed to cope with the environmental and social problem of desertification.

One of the most important factors affecting to the vulnerability of the Mediterranean areas is drought. Drought is a passive and non-dramatic meteorological phenomenon, but its impact can be very severe (Bruins, 2003). Drought builds up gradually as the cumulative effect of below average precipitation in a certain area during a certain time period and it affects more people than any other natural hazard (Wilhite, 2000).The resulting decline in water reserves causes conflicts between users.

To mitigate the effects of drought and its impacts on food security in Mediterranean countries, drought planning on a national and regional scale must be developed. Severe drought periods increase risk of desertification so emergency water management mechanisms, developed proactively within the appropriate governmental context, are needed (Bruins & Lithwick, 1998). A drought coordinating entity is necessary for both planning and management purpose, with clear executive powers in social and governmental terms (Wilhite, 2000).

Warmer and drier times ahead?

The Mediterranean climate shows sings of change. Observations suggest that climate may already be changing in the region. Land records for the western Mediterranean show slight trends towards warmer and drier conditions over the last century. Probably, while all such trends and extremes events could have occurred naturally, they are broadly consistent with the potential effects of greenhouse gas emissions and aerosol emissions to date. It is known that if current trends in emissions of greenhouse gases continue, global temperatures are expected to rise in this century more than any other time in the last 10,000 years. For instance, during the second half of last century, in Murcia (Southeast of Spain) the increase of average temperature has been of 2ºC (López-Bermúdez & García-Gómez, 2002). In Valencia the increase had the same order of magnitude (Quereda *et al*., 2001). Higer temperature means more evapotranspiration, more water stress and more risk of desertification. Significant uncertainties surround predictions of regional climate changes, but it is likely the Mediterranean region will also warm significantly (IPCC, 2001).

The outlook for precipitation is much less certain, but most projections point to more precipitation in the winter and less in the summer over the region as a whole. A common feature of many projections is declining annual rainfall over much of Mediterranean region south of 40º - 45º N, with increases to the north of this. Even areas receiving more precipitation may get drier than today due to increased evaporation and changes in the seasonal distribution of rainfall and its intensity. As consequence, the frequency and severity of droughts could be increased across the region. Changes in large-scale atmospheric circulation represented by the global teleconections as El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO) and the influence of Sahara desert, would further affect the occurrence of extreme events (Balairón, 1997).

The consequence of this trend towards more irregular and heavy precipitation and more aridity is an increase in extent and severity of desertification. Climate change effects (warmer and drier conditions), combined with wider socio-economic-political factors, would extend the area prone to degradation northwards to encompass areas currently not at risk. In addition, the rate of desertification would increase due to increase in soil erosion, soil and water salinisation, fire hazard, loss of biodiversity, increased frequency of water shortages, reductions in water availability, decline in water quality, reductions of soil quality and productivity, etc. As a result, the process of desertification is likely to become irreversible.

The environmental, economic and human cost of an increase in desertification would be enormous, however, the most important issue arising from desertification is the loss of food security by declining production, rising demand by population and price increases. The reductions in food security would increase the risks of malnutrition and hunger for millions in the Mediterranean south countries. The extreme weather events could increase death and injury rates.

Food Security

The Rome Declaration (1986) affirms the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger. FAO defines a good food security condition as the situation which all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This concept includes the aspects of quantity and quality. There are three dimensions implicit in this definition: *availability* (sufficient food supplies should be available to meet consumption needs), *stability* and *acces*s (even with bountiful supplies, many people still go hungry because they are poor and unable to produce or purchase the food they need). In addition, if food needs are met through exploiting non-renewable natural resources or degrading the environment, there is no guarantee of food security in the longer-term

At the household, regional or national levels, purchasing power is used as an indicator of security. At the national level two other concepts are considered:

Food self-sufficiency, which means the capacity of domestic supplies to meet maxium possible food needs, thus minimising dependence on trade.

Food self-reliance, takes into account the possibilities of international trade and means maintaining some level of domestic food production while generating the capacity to import from the world market as needed. The problem with reliance on trade is the uncertainty of supplies and world market prices.

A new concept: Food sovereignty emphasises every country's right to autonomously define his national agricultural and fishing policies and, regarding food, the right to protect and regulate the national agricultural economy and the national market in order to reach sustainable growth levels. The main differences between this concept and food security is that food security stresses covering the population's need of food, detaching this aspect from the productivity of farming and fishing as well as from trade. Many NGO's and social movements have adopted the more complex definition of food sovereignty in order to protect and promote the small farmers activities.

Causes for food insecurity

The Rome Declaration indicates poverty as a major cause of food insecurity. Sustainable poverty eradication is considered critical to improve access to food. Conflict, terrorism, corruption and environmental degradation also contribute significantly to food insecurity. It is demonstrated that, when poverty decreases, so does hunger.

Worldwide, 840 million people are going hungry including 790 million in developing countries and 40 million in north Africa and near East (FAO 2002b), it is estimated that 75% of poor people live in rural areas (where 60 % of the world population live) and they live by farming, cattle or fishing activities (IFDA, 2001). In more than 100 countries more than 50% of GDP comes from agricultural activities. In addition, hunger, poverty and drylands are closely related, since 80% of the world's poorest countries are mainly dryland areas (World Bank, 1999).

In the Declaration of Rome FAO pointed out poverty as the main factor for food insecurity. The United Nations developing program indicates the reasons for persistent poverty in drylands. They include: geographical and political isolation, the lack of services, especially health, extension and education; lack of agricultural inputs, inadequate access to markets (for buying inputs and selling products lack of land tenure, gender discrimination, lack of financial benefits flowing to the local community from local resources or inadequate access to those resources, high vulnerability to drought, lack of insurance and over-cultivation, over-grazing and subsequent loss of the productive potential of land: desertification. Fighting poverty in the drylands requires tackling all these problems simultaneously. From 1970 to 1990, poverty and hunger rates decreased as never before. However, since then, progress has declined and in the last decade it was only one third of that required to reach the UN goal of reducing 50% the poverty levels by 2015 (IFAD, 2001). FAO affirms that this commitment will not be possible to reach (FAO 2002c). From 1990 to 1997 the number of undernourished people was reduced by 40 million people but this statistic hide the fact that while in 37 developing countries the number of undernourished people was reduced by 100 million people in the rest of the developing world it was increased by 60 million people (FAO 2002c).

World food security is determined by poor farmers' production methods and poor consumers' purchasing power (FAO, 2000b). Mere economic growth is not enough to reduce poverty levels, particularly in countries where the number of poor people is high. In countries where the initial inequalities are high, the poor must be provided access and control over resources (land, water, etc.), markets, technologies and institutional programs. Therefore, in order to decrease poverty levels, more determined actions are needed focusing small and poor farmers (IFAD, 2001). Most of the people suffering from food insecurity live in rural areas and their ways of subsistence are related to agriculture (FAO, 2002c). However, at present, poor farmers are often excluded from high value-added markets because they lack access to resources (Oxfam, 2003).

The relationship among food security, poverty and desertification is clear. As drylands are plagued by both food security problems and high desertification risk, these two issues must be managed together. Combating Food security and desertification is a matter of resources management. Actions taken to manage one of these issues will affect the other. In the following sections we consider factors affecting food security and its relationship with desertification. We are focusing on four main factors that affect the food security status:

Exhaustion of Natural resources. Unsustainable use of natural resources, due to either an increase in population pressure or inadequate land management, reduces food security status for following generations.
Irregular (or unfair) access to resources: land, water, biodiversity, forests… In some cases where enough resources to assure food security in one area are present, food security problems occur because access to these resources is not equal for the whole population. This is caused by insufficient or non-existent land or social policies.
Economic and trade policies for agriculture. Agricultural policies, particularly those directed at trade in agricultural products, can be very useful in assuring food security. On the other hand, policies can also significantly increase the risks where they are wrongly developed. Food self-sufficiency and food self-reliance are very important factors to take into account in these policies
Natural disasters and humanitarian catastrophes. Already existing desertification processes, climatic change, floods, droughts, etc. contribute to worsen the situation. The problem is worse in countries where social policies to protect farmers from the effects of these disasters do not exist.
We have selected, from these issues, some factors, which we consider relevant for the relationship between food security and desertification:

Small Farmers

Small farms are the most fragile part of the world's agricultural structure. They are the central to dealing with the issues of poverty and hunger in developing countries and one of the key factors in dealing with rural depopulation in developed countries and with desertification world wide. Rural growth based on smallholder farming is a powerful catalyst for poverty reduction because it concentrates income among the poor (Ravaillon and Datt 1999; in Oxfam, 2003). Rosset (1999) suggests that a small farm model for agricultural development could produce far more food than a large farm pattern ever could. Also IFAD (2001) and FAO (2000a, 2002a, 2002b) mark the importance of small farms. The initial perspective is that an approach based on high density labour force is especially suitable for decreasing rural poverty since both capital and land are in short supply in low income countries.

Staple production of food from small farms plays a major role in the subsistence of poor farmers. This production contributes to most of the work, incomes, and calories consumption (up to 80%). Small farmers tend to be multi-functional and can be more productive, more efficient and contribute more to economic development than large farms. Small farmers can also make better stewards of natural resources, preserving biodiversity and safe-guarding the future sustainability of agricultural production. Small farming has more benefits for the local communities in terms of use of manpower, more dynamic and better supplied local markets, local inputs, and increased participation. Encouraging small farming is also an effective social policy for stopping migration (Rosset, 1999).

Shibata (1999) emphasises the importance of anchoring programmes firmly to the local economy. Another important factor is the position of women. As they shoulder a lot of the farming work, issues of support and equality require attention. On the other hand, also non agricultural rural activities must be promoted as they can complement agricultural development and increase demand in poor areas (IFAD, 2001).

It is necessary to point out that, when it comes to desertification, leaving some areas un-cultivated or stopping cultivation in some areas is as important as the support of cultivation in other areas. Farming must be considered as the first and most efficient strategy to cope with desertification. While the management practices of small farmers can be very effective in combatting desertification, small farming is also an effective way of assuring sufficient food security levels.

Land tenure

It is estimated that 80% of land in developing countries is owned by 3% of the population (Leahy, 1997). The United Nations Development Programme (UNDP, 2003a) affirms that it is not the type of tenure but the security and the equity of resource access which together will determine whether land tenure reform will lead to sustainable development on both ecological and socio-economic criteria. In drylands this imperative is complicated by the typical reality of multiple users accessing the resources of an area (grass, water, etc) at different times or even at the same time but in different ways (UNEP, 2001). The solution, however, is not necessarily land titling. The solution is most likely some form of locally specific regulations (UNEP, 2001). In those places where the state structures can not play his role efficiently, local communities must be empowered. Participatory and decentralized approaches have proven efficient in many cases (IFAD, 2001).

Moreover, women tend to benefit from collective ownership. Land redistribution, recognition of communal land rights […] and provision of services to women farmers, all have a key role to play in extending opportunity (FAO, 2000a). Higher levels of security in land tenure –not necessary formal tenure- would decrease the time spent in trying to assure rights and, therefore, increase the time that can be used for productive activities. Secure tenure conditions can also help to assure access to credit. In occidental Africa the land rental markets are very dynamic. If this activity could be increased the economic activity in rural areas would increase (Deininger & Muñoz, 2003).

Land tenure systems and desertification are clearly related issues. In some countries collectively owned land becomes the property of those who have cultivated it for several years and the wish to own land thus act as one of the main incentives for clearing and cultivation (Floret *et al*, 1993). On the other hand if people do not have land titles, they have no incentive to invest in long-term improvements, especially on rented land (UNECA, 2002). It is only possible to develop actions against land degradation when there is some feeling of tenure that can assure some degree of compromise from the users.

Trade and subsidies

Agricultural trade expanded in the second half of the 1990s at less than one-third of the rate for trade in manufactured goods. Industrialised countries account for about three-quarters of both global exports and imports of agricultural products (OECD, 2000). Forecasts for the future show that developing countries will increasingly be depending on staple food imports (FAO 2002c). The globalization of markets leads to more instability and not necessarily to economic growth (Stiglitz, 2004). Poor people are likely to benefit more from trade liberalization if they have equitable access to markets and resources (IFAD, 2001; FAO 2002c). That is why trade policy has to be seen as an integral part of national poverty reduction strategies (Oxfam, 2003; FAO 2002c). Third world countries have been inundated with cheap food that drives down the prices. Agricultural producers suffer welfare losses as a result of lower prices, while consumers make short-term welfare gains. This has important implications for food security (Oxfam, 2003). Moreover, while low food prices might bring benefits for poor consumers, they are less advantageous for small farmers seeking to earn income from sales of food surpluses. Subsidised exports from rich countries may reinforce a tendency to supply urban centres from world markets, rather than from domestic rural areas. This in turn is likely to undermine prospects for rural growth and weaken the linkages between the farm and non-farm linkages vital for poverty reduction. Drop in farm prices can drive farmers off the farm. The farmers that carry on must intensify the production or get new lands to support a family. Poorer farmers abandon and large farmers with different model of farming occupy the land. Food security is at risk: domestic food production falls in the face of cheap imports, land once used for grow food is placed into production of export crops for distant markets. People now depend on money rather than land to feed themselves. Fluctuations in employment, wages and world food prices can drive millions into hunger.

Flexibility to use policy instruments to protect the livelihoods of the poor (producers as well as urban consumers) from import shocks is needed. In order to raise domestic production (for tradable and non-tradable products) poor farmers should, whether temporarily or not, be protected from negative external shocks (market fluctuations). The solution may be to use policies or investments targeted to farmers directly, rather than using indirect methods to influence food prices which inevitably lead to leakages and additional distortions (Mamaty, 2002). Poor people can not depend on distant global markets for the daily meals, local markets must be promoted.

OMC statistics show that agriculture products represent 9.3 % of total world trade in 2002. As in most industrialised countries, agriculture accounts for a small share of GDP, while agricultural exports exceed one-third of the total in almost half of all developing countries (FAO, 2000a). Egypt's and Algeria's share of agricultural imports over total imports is over 30%, Morocco is 17% and Tunisia 13%. In fact, all the North Mediterranean countries are in the group of countries with the highest share of agricultural products in economies (???) total merchandise imports. On the other hand, the share of agricultural products from Africa in the world market was 3.8% in 2002, the same as in 1995 (the share of African products in world merchandise trade has decreased, between 1990 and 2002 from around 3% to around 2%). Poor areas (as dry areas are) must be supported, and the development of marketing infrastructure in those areas is needed (FAO 2000).

When it comes to low productive areas (as drylands in the Mediterranean area), where agriculture provides food and joint public goods, the decrease in farming activity threatens the local supply of public goods such as the quality of rural life, agricultural biodiversity, etc. Desertification leading to the loss of these public goods justifies specific policies to protect or promote these goods. Therefore, the agricultural subsidy is generally more adapted to these low productivity areas, because the economies of scope are likely to be larger than the market deadweight loss. On the contrary, the non agricultural supply of public goods (by the state) is more adapted to areas where land productivity is higher (Le Cotty, 2002).

Water Scarcity

At the global level, 50% of the easily available water resources are in use. In the year 2030 the percentage is expected to increase to 64%, which means 20% of the total water available. 70% of this water is dedicated to agriculture and 30% to industry and human supply (Sagarduy, 2003) (Table 2). The problems are serious at the regional level, with high continental imbalances. In arid countries water dedicated to agriculture can reach 90% of the total uses.

One of the models developed to assess water demands in the future shows that in North African and Near-East countries water won't be sufficient to assure food security, health and environment (Sackler *et al.* 1998). In Sub-Saharan countries the situation will be worse, while in North Mediterranean countries water resources must be developed in order to avoid scarcity. The Mediterranean countries are classified, attending to the status of the water resources as (Sagarduy, 2003):

- Countries where water availability will not be sufficient to assure food security so they have to transfer from domestic or industrial uses: North African countries (Libya, Egypt…).
- Countries that have to increase present resources between 25 to 100 % (Turkey, Morocco, Algeria…).
- Countries that must develop present resources between 10 to 25% (North Mediterranean countries).

Water scarcity is not only related to insufficient quantity available but also to poor management of water resources, inadequate access to, and rights over, water. In order to assure food security in the future it would be necessary to expand irrigation farming in developing countries by 45 million ha but increasing water availability is not easy. It is necessary to improve water management. Reduction in rural poverty needs a better allocation and distribution of water to increase staple food production. Many drylands suffer from water stress and there are also huge pressures to divert water from agriculture to urban areas and industrial uses (IFAD, 2001).

Climatic Change

One of the most dangerous effects of climatic change is the increase in the extent and severity of desertification. This will lead to significant changes to future scenarios for farming and food security. The magnitude of the changes will be determined by the availability of water and soil (Palutikof *et al*., 1992; Imeson *et al*.,1994;Thornes, 1995; Ibañez *et al,* 1997; Balairon, 1997; López-Bermúdez, 2001; WMO, 2003). Livestock production will suffer due to deterioration in the quality of rangeland associated with higher concentrations of atmospheric carbon dioxide and to changes in areas of rangeland as climate boundaries move northwards. In the European Mediterranean, the area of unproductive shrubland is expected to expand, while in North Africa and the Near East, most of the steppe rangeland could give way to desert by 2050 or earlier. These lands are currently receding across the region, but particularly in the south where some 50% of arid steppe rangeland has been cleared for crops over the last 30 years (Le Houérou, 1992). This ever-increasing clearance is also a major cause of desertification in northern Africa and the Near East (Le Houérou, 1988). This fragmentation of rangeland may add to their vulnerability to climate change (Archer, 1994). As the IPCC point out, "[with] the addition of climate change to existing impacts, rangelands may be more susceptible to extreme events such as drought, 100-year floods, and insect outbreaks" (Allen Diaz, 1996).

Assessing the impacts of climate change on food security is immensely complex. To do so, requires not just climate and crop modelling, but also economic modelling of the world's trading system - thus adding yet another level of uncertainty. In 2030 climatic change is expected to reduce 2-3 % the cereal production. Selected seeds and increase in the use of fertilizers can balance it, but this issue will difficult the progress in food production (FAO, 2000a). World prices for many key commodities such as wheat, maize, soybean meal and poultry could rise significantly as a result of global climate changes. The combination of higher prices and crop losses would lead to a deterioration in levels of food security in, particularly, southern countries. The losses to the national economy would have serious implications for the food policies of many underdeveloped countries and on the lives of thousands of pastoral people (Allen-Diaz, 1996; FAO, 2000a).

SPECIFIC FACTS FOR THE MEDITERRANEAN AREA: MAIN CONTRASTS BETWEEN NORTH AND SOUTH

Desertification is one of the factors that can affect food security in the Mediterranean region as desertification and land degradation are directly connected (Brandt & Thornes, 1996; López-Bermúdez, 2001). The migration movements, the water scarcity and the climatic change can accelerate desertification processes and put more pressure on food security issues. On the other hand, actions taken to cope with food security problems can put more pressure on desertification processes, accelerating a vicious circle.

There are many social, economic and political differences between the north and south Mediterranean areas. As shown in Table 1, population growth will differ on both sides from now to 2050 (Brauch, 2002). It will decline in the north (-23 million people) and it will increase in the south (+181 million). Moreover, this population increase will be placed in fragile lands.

Table 1. Population growth (x 1000) (1900-2050) in Mediterranean area
Source: Brauch, 2002 (adapted)

	1900	***1950***	***1965***	***2000***	***2050***	***1950-2050***	***2000-2050***
France	41,000	41,829	48,753	59,238	61,832	20,003	2,594
Greece	4,500	7,566	8,551	10,610	8,983	1,417	-1,627
Italy	34,000	47,104	52,112	57,530	42,962	-4,142	-14,568
Portugal	5,500	2,996	9,129	10,016	9,006	6,010	-1,010
Spain	18,500	28,009	32,065	39,910	31,282	3,273	-8,628
Total (5)	**103,500**	**132,913**	**150,610**	**177,304**	**154,065**	**21,152**	**-23,239**
Cyprus	0,230	0,494	0,582	0,784	0,910	0,416	0,126
Malta	0,190	0,312	0,305	0,390	0,400	0,088	0,010
Albania	0,800			3,134	3,905	2,690	0,771
Yugoslavia	9,500			23,205	20,088	3,743	-3,117
Algeria	5,000	8,753	11,823	30,291	51,180	42,427	20,889
Morocco	5,000	8,953	13,323	29,878	50,361	41,408	20,483
Tunisia	1,500	3,530	4,630	9,459	14,076	10,546	4,617
Libya	0,800	1,029	1,623	5,290	9,969	8,940	4,679
Egypt	10,000	21,834	31,563	67,884	113,840	92,006	45,956
Only North Africa	**22,300**	**44,099**	**62,962**	**142,802**	**239,426**	**195,327**	**96,624**
Jordan	0,300	1,237	1,962	4,913	11,709	10,472	6,796
Israel		1,258	2,563	6,040	10,065	8,807	4,025
Palestine A.	0,500		?	3,191	11,821	10,816	8,630
Lebanon	0,500	1,443	2,151	3,496	5,018	3,575	1,522
Syria	1,750	3,495	5,325	16,189	36,345	32,850	20,156
Turkey	13,000	20,809	31,151	55,668	98,818	78,009	43,150
Eastern Med,	**16,050**	**29,247**	**43,152**	**89,497**	**173,776**	**144,529**	**84,279**
10+1 dialogue	**38,350**	**73,346**	**106,114**	**232,299**	**413,202**	**339,856**	**180,903**
TOTAL	***152,570***	***219,216***	***257,611***	***437,116***	***592,570***	***373,354***	***155,454***

The South

For a number of reasons, Africa can not simply clone nutrition programs from other regions. Africa is different. The population density is lower, seasonality of climate more dramatic, population growth higher and agroecological conditions more variable. Africa also has lower levels of urbanization and worse physical infrastructure, as a whole, than other regions. (Abosede and Mcguire, 1991). FAO’s statistics show the dependence on cereals and pulses in developing countries (one inhabitant of Africa consumes 35 kg of cereals more than an European inhabitant and 4 times less animal fat every year). The expected increasing needs on vegetables, eggs, meat and milk are the reason for future increases in land agricultural uses in Africa. Cover index (production/demand) in North Africa is now 65%. In 2030 it is expected to be 56% (FAO, 2002a).

Although a net food exporter before 1960, Africa has become more dependent on food imports and food aid over the past three decades. During 1974-90, food imports in sub-Saharan Africa rose by 185 per cent and food aid by 295 per cent (UNDP, 2003b). In 1995, food imports accounted for 17 per cent of total food needs in the region. That rate is projected to at least double by 2010 (Nana-Sinkam, 1995; in UNEP, 2000). Cereal imports in developing countries are projected to more than double by 2030. Each region will show significant growth, with the Near East and North Africa continuing to account for the bulk of imports (FAO, 2000a)

Slow progress in increasing food production has meant decreasing per capita supplies for many Africans over the past 40 years (UNEP, 2000) (Fig. 1). Per capita land has now declined from about 0.5 ha/person to less than 0.3 ha/person. Although there are an estimated 632 million hectares of arable land in Africa, only 179 million hectares are actually cultivated (FAOSTAT). As with other natural resources, arable land is unevenly distributed. More than 246 million hectares of the as yet uncultivated arable land, representing nearly 40 per cent of the remaining total in the region, is found in only three countries (the Democratic Republic of the Congo, Nigeria and the Sudan) (UNEP, 2000). In 2030 food production in developing countries will be 70% higher than now, and the irrigated areas in developing countries will be increased from 20 to 47% (FAO, 2002a).

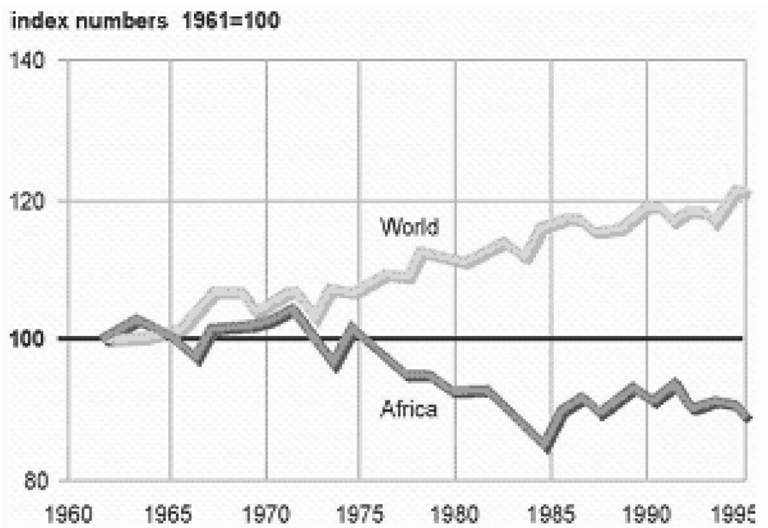

Figure 1. Food production per capita. Source: FAO, 2002a

The productivity of the African farmer is low for many reasons including non-adoption of modern technologies, insufficient availability of capital for off-farm *inputs* and land tenures (Reich *et al*, 2001). Land degradation is a major factor in constraining food production in Africa to only a 2% per cent average increase, much lower than the average population growth rate.

Rangelands sustain a large number of people in the Mediterranean region (livestock and forage crops). More than 50% of them have been cleared for crops in the last 30 years (UNEP, 2000).

Degradation in drylands tends to be greatest in the dry sub-humid zones, the most densely populated areas of the drylands (World Bank, 1999). Nearly 40% of Africans live on fragile lands. About 500 million hectares in Africa have been affected by moderate or severe soil degradation since about 1950 including 65 per cent of the region's agricultural land (UNEP, 2000). Crop yields in Africa could be halved within 40 years if degradation of cultivated land continues at present rates (Scotney and Dijkhuis 1989; in UNEP, 2000). About 50% of land degradation is caused by overgrazing, 24% by crop production, 14% by clearance of vegetation for agriculture, and 13% by overexploitation (UNEP, 2000). Overgrazing has reduced range productivity virtually everywhere outside the tsetse fly regions, in north, west, east, and south Africa (Dregne, 1986). Although overgrazing has long been considered the primary cause of desertification in Africa, it is now thought that rainfall variability and long-term droughts are more important determinants (UNEP 1997; in UNEP 2000).

The increase in human and animal population and the injudicious use of technology has also a major role in land degradation (Dregne, 1986). Degradation has increased desertification, decreased land productivity, and caused losses of arable land (UNECA, 2002). It has had also significant effects on agricultural supply, economic growth, food security for poor farmers, long term value of nationally important land and environmental values such as water quality and biodiversity (Scherr, 1999). Degraded land produces less food, reduces the availability of biomass fuel, makes ecosystems less resilient, and increases malnourishment and susceptibility to disease in local populations (UNECA, 2002). Other factors that lower food self-sufficiency and security in Africa include pests and diseases, inappropriate food production and storage practices, inadequate food processing technologies, civil wars and the low economic status of the women, who produce the bulk of the food. Unless urgent and effective land conservation and watershed management measures are taken, food insecurity will continue to be a critical local, national and regional problem (UNEP, 2000). As a consequence of some of these processes, there commonly occurs societal disruption due to reduction in life-support systems (Eswaran *et al.,* 2000).

In North Africa and the Near East, changes in average climate associated with a doubling of carbon dioxide could cause yield losses of over 20% for wheat, corn and other coarse grains In coastal areas, large areas of productive land may be lost through flooding, saline intrusion and water logging.

The North

In the North Mediterranean countries the erosion problems are very important. 12% of the area is affected by water erosion and 4% by wind erosion, generally as a result of unsustainable agricultural practices (Mairota *et al*., 1998; Brandt *et al*., 1996; UNEP, 2000; Geeson *et al*., 2002). The area of unproductive shrubland is expected to expand.

The approach to food security issues in north Mediterranean countries is quite different to the approach in southern countries. The concept of food security is the “desired” ratio of imports over domestic production (Mamaty, 2002). The economic and technological development (including the green revolution) assured the food availability, stability and access to food in Europe after the II world war. The low increase in population of the last decades will continue at the same level, so low increases in food demands are expected. Nowadays, crop production remains important for both domestic food consumption and the generation of export income in the Mediterranean region. Currently, Mediterranean agriculture accounts for nearly all the olive oil production world-wide, 60% of wine production, 45% of grape production, 20% of citrus production and about 12% of total cereal production. The main processes related to food production is migration from the country to the cities and the decreasing population dedicated to farming activities, from 15 mill to 4 millions since the 50’s to nowadays. In Europe there are almost 7.000.000 farms, but only 3% of them have over 100 ha and they produce 50-70% total *outputs*. Only 17% of farms get 50% of the subsidies while 39% of the small or medium farmers get only 8% of the resources (EUROSTAT; in Oxfam, 2002).

In Spain 85% of the farms have less than 10 ha (Tamames, 2002). In the latest CAP (EU farming policies) reforms a new model of subsidies has emerged, detached from production and area cultivated. These measures, in spite of possible negative effects, could change the distribution of subsidies. Another problem is that population in the country is becoming increasingly older and when farmers retire there are no young farmers to substitute them. Land abandonment is a major issue. The possible problems (apart from environmental and socio-economic problems) can be related to Food self-sufficiency and Food self-reliance.

It is possible to find two different farming models in Mediterranean Europe: (a) intensified farming, using more and more inputs. In some cases there are negative environmental effects associated with this production, (b) small farms, often with dry farming activities. They are becoming extinct**.**

As an example we can consider the almond cultures in the Mediterranean. Spain represents 44% of the global area dedicated to this culture. One aspect of the EU funded DESERTLINKS Project focuses on the Murcia Region (southeast of Spain), aiming to identify the driving forces that condition dry land farmers decisions to abandon the almond culture and the consequences of this action. The almond cultivation represents 56% of total dry farming area cultivated in Murcia and 23% of the total agriculture area cultivated in the region. Data from more than 1000 farms were collected. More than 35% of the farms are less than 5 ha in size, and only 3,5% of the farms are more than 50 ha. The conclusions, which could be also applicable to other cultures in the Mediterranean areas, were that:

- In absence of water availability, the CAP is the main driving force for farmers, especially the subsidies policies.
- Almost none of the farms would be profitable (economically) without subsidies.
- They play a very important role for stopping desertification (labours and management programmes) and for local economies, as an extra income for farmers and for small industries.
- The situation of the culture could be used for environmental (forestation or land restoration) and social (maintaining farmers in rural areas) aims:

The almond farming in Murcia is very important for the local economy. They are also important for food industries in the southeast of Spain. Almond cultures in the area can not compete with American cultivations (irrigated cultures with 3 times more crop production) but on the other hand the American produce is not suitable for food industries, so the substitution of the production would have negative effects for a huge socio-economic group. Regarding environmental effects, in some cases almonds are cultivated on hill slopes and thus forestation programmes to change the land use would be necessarily, but in other cases land abandonment would lead to land degradation and expensive programmes to avoid the problem. Studies demonstrate that specific politics and support in lower productivity areas are not only necessary but also economically profitable (Leccotty, 2002; Oxfam, 2003). When markets do not exist to allocate costs and benefits of agri-environmental impacts and outputs, policy action may be needed to account for the costs of not respecting environmental targets and to ensure the provision of environmental benefits (OCDE, 2001).

SOLUTIONS

Increasing the availability of food

Sufficient opportunity for the production of food is a more crucial factor of food security than the capacity to purchase food. Poor people can produce but can not buy. In areas with increasing population it is assumed that, in order to meet these necessities, a combination of enlargement of cultivated areas and intensification are needed (FAO 2002a, Trueba, 2002; Sagarduy, 2003). Studies showed that the most limiting factor for the expansion of farming land is the availability of land, rather than the availability of water. In the near-east and North African areas 87% of the suitable land for cultivations was already in use in 1997-99 (FAO, 2002a). According to this, it is estimated that 80% of the new supplies will be obtained from intensification (Sagarduy, 2003).

(i) Enlargement of cultivated areas. The present cultivated area is about 1500 million ha. It is estimated that this area must be increased by 120 million by 2030 (it was increased by about 165 million ha from 1960 to 2000). Food production in irrigated areas must increase from 40% to 47% of total food production by 2030 and irrigated lands in developing countries must be increased by 45 million ha. This is a very difficult task, since the economic efficiency of developing new irrigated areas in these countries is decreasing, mainly due to the effort needed to access new water resources and the fall in vegetable prices. The expected enlargement of cultivated areas in North Africa and the near-east is about 6%.

(ii) Intensification. Productivity intensification can be achieved either by increasing cultivation intensity or by increasing crop yields. In irrigated lands, intensification can be achieved by:

- Meeting the modernization necessities that 80% of the 267 mill. Ha irrigation lands have.
- Increasing the farming intensity from 129% to 140%.
- Increasing water use efficiency from 38% to 42%
- Increasing Cereal crop yield from 3.82 t/ha to 5.16 t/ha, mainly in developing countries.

The cost of these actions is calculated as about 100 to 1000 $/ha (Sagarduy, 2003). The consequence of failing in this expectative is the increase in cereal prices. It would lead to a lower per capita consume of poor people and the situation of food insecurity for many countries would worsen. The number of undernourished people would increase from 790 million to 1200 million, most of them children and young people. Economic situation in poorest countries would worsen since they should assign more funds to food imports. Finally, unemployment would be increased in developing countries as agriculture wouldn't be able to absorb labour force. In short food insecurity would be increased from the present situation.

Technological changes are needed in areas with scanty land availability or with limitations for food production (water, soil quality, climate...). Often these areas have a high population density, in which case technology would help to improve food security (FAO, 2002a). Technological changes can help if they are properly disseminated (Abosede and Mcguire, 1991). Resources (research, subsidies…) are focused on export products, it is necessary to change this (conservation measures, drought adaptations…). Regarding this issue, it is also necessary to encourage farmers to grow traditional crop varieties more suited to local climates, employ irrigation methods that consume less water (micro-irrigation, "fertigation", etc.) and adapt agricultural consumption to the water available (Council of Europe, 2000). Also, since there is not much more land available in some areas, it is necessary to develop land reforms including land tenure initiatives. On the other hand diversification of products and activities is necessary. Increase in off-farm incomes would provide new incomes for farmers and economic growth

Finally, it is not only the production that is important, but also the distribution. Investments in rural areas are necessary. Better infrastructures and support for local markets and local production are needed.

Making changes in markets, subsidies and policies

Policy packages that reduce distorting subsidies without causing hardship, particularly to poor sectors of the population and small-scale industry, are badly needed. Cutting the link between support measures and resource use, leaving the support intact but removing the perverse incentive, is a first step. It is also important to raise awareness, amongst the general public and others, of the linkages between subsidies and environmental degradation, and of the impact of subsidy size (UNEP, 2000). Subsidies must be changed but not eliminated since the cultivation in some areas for social, environmental and food security reasons is necessary. Export subsidies distort the market and damage poor rural economies. On the other hand, subsidies for local production and local markets must be developed. Support for local communities is the most suitable action to combat desertification and to improve food security. Women must be especially supported for their role in bringing up the family.

Analyses in countries such as Morocco (Laraki, 1989) suggest that subsidies on 'inferior foods' not consumed by the wealthy would reduce the welfare costs to the poor. The agricultural subsidy is generally more adapted to low productivity areas, because the economies of scope are likely to be larger than the market deadweight loss. On the contrary, the non agricultural supply of public goods (by the state) is more adapted areas to where the land productivity is higher, for symmetric reasons. If multifunctionality is understood as a joint production of commodity and non commodity output, then agriculture is more multifunctional in areas affected by desertification, meaning that the necessity to maintain the connection between the production of food and non-market goods is more critical in those areas. A reasonable subsidy to farming in low productivity areas would be beneficial to the state welfare in both types of areas (intensified and desertified areas) (Le Cotty, 2002). When talking about subsidies in agriculture and consequent implications for food security, farming activities should be divided into two groups:

- Farm activities directed at export the production and to compete in world markets: subsidies to these activities should be focused on innovation and environmental improvement
- Farm activities directed at local markets or "social agriculture" (important for environmental and socio-economic issues): subsidies should be focused on supporting the activity and maintaining population in rural areas.

Commercial activity can be a very important promoter of poverty reduction, combined with economic aid (Galián, 2002). A very slight increment of exports could become a significant increase in the incomes for the developing countries, but access to markets is required. FAO (FAO, 2002c) suggests that the development of agriculture in developing countries requires flexibility of trade rules and protection of local markets and farmers. It is also important to improve the access of these farmers to markets in developed countries. On the other hand, the high level of agricultural support in developed countries should be reduced as it is stopping agricultural development in developing countries. Poor countries can be very effective and competitive in staple food production. Free trade is not a solution to food security because poor people have the problem of access to world markets.

CONCLUSIONS

Food security issues must include quality and biodiversity support, long term objectives that have been replaced by urgent problems in the south. Food security issues and CAP must include desertification as one of the major issues. Strategies to ensure food security should include increased measures for environmental protection while dealing with the need to increase production to meet need. Desertification and food security are the main challenges for the Mediterranean area this century. To combat these problems holistic and decided attitudes must be developed. Small farmers must be supported, supported in the north (before they become extinct) and supported in the south (to provide food security). Land policies are necessary to assure the access to resources for poor people. Regarding trade, it can have positive or negative effects on desertification and food security. Local markets must be supported. Trade won't mean development for developing countries until food security, which leads to social stability and economic development, especially in rural areas, is not assured.

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PART V

Soil and Vegetation Monitoring

MONITORING TOOLS TO ASSESS VEGETATION SUCCESSIONAL REGRESSION AND PREDICT CATASTROPHIC SHIFTS AND DESERTIFICATION IN MEDITERRANEAN RANGELAND ECOSYSTEMS

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ABSTRACT

The relationship between grazing intensity and ecosystem performance is complex and can depend on the prevailing ecological conditions. Previous studies have revealed that, in traditional grazing ecosystems, grazing can reduce ecosystem diversity in poor soils, but increase diversity and productivity in rich ecosystems subject to moderate grazing pressure. We are interested in detecting long-term structural changes or drift in an ecosystem before it is too late to prevent irreversible degradation. We analyzed vegetation spatial patterns and complexities of four Mediterranean communities: Tihmadit Region (Middle Atlas, Morocco), Camiyayla (Namrum) Region (Taurus Mountain, Turkey), Sykia Region (south of the Sithonia Peninsula, Greece), and Cabo de Gata Nijar Natural Park, Spain. Grazing disturbance was most intense near shelter and water points, which lead to gradients in soil surface disruption, compaction, and changes in the composition and cover of perennial vegetation. Dense matorral was more resistant to species loss than were moderately dense and scattered matorral, and grassland. Information fractal dimension decreased as we moved from a dense matorral to a discontinuous matorral, and increased as we moved to a more scattered matorral and to a grassland, which resulted in two opposing processes (interaction declining with ecosystem development, and immigration increasing with degradation) in a common pattern, i.e., small patches homogeneously distributed in the landscape. Characteristic species of the natural vegetation declined in frequency and organization in response to higher grazing disturbance, while species of disturbed areas exhibited the opposite trend. Overall, the spatial organization of the characteristic plants of each

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community decreased with increasing vegetation degradation, with the intensity of the trend being related to the species' sensitivity to grazing. Developmental instability analyses of key species were used to determine the sensitivity of dominant key species to grazing pressure. Palatable species, which are better adapted to being eaten, such as *Periploca laevigata*, *Phillyrea latifolia* and *Genista pseudopilosa*, were able to resist moderate grazing pressure, while species of disturbed, grazed sites did not change developmental instability in response to increasing grazing pressure, such as *Thymus hyemalis*, *Teucrium lusitanicum* and *Cistus monspeliensis*. The usefulness of these monitoring tools in preventing land degradation is discussed.

INTRODUCTION

Mediterranean ecosystems are characterized by highly heterogeneous and fluctuating environments where overgrazing and fires, together with episodic droughts, result in land degradation (DiCastri and Mooney, 1973; DiCastri *et al*., 1981). Landscape preservation in such situations is complex and influenced by interactions among grazing pressure, rainfall, edaphic conditions and grazing history (Milchunas and Lauenroth, 1993). Climatic variability and grazing history are the principal forces affecting species composition and productivity (biodiversity and stability) in rangeland semi-arid ecosystems, which are concentrated on marginal areas where grassland productivity is relatively low. Nomadism and transhumance were the traditional ways of adapting to episodic drought in the Mediterranean region, which allowed an ecological balance between production and exploitation. But, transhumance has become more sedentary in many areas of the Mediterranean in recent decades (Aidoud *et al*., 1998; Rebollo and Gomez Sal, 1998; Ruiz and Ruiz, 1986) and farmers use supplementary products from agriculture during periods of scarcity.

It is well accepted that many ecosystems will adapt to a disturbance if the disturbance persists over a long period and that it can be considered to be a part of the environment (Peterson, 2002), to a point where the absence of disturbance can become a disturbance in itself. Evolutionary changes observable over less than a few hundred years (contemporary evolution) are associated with the same factors that are driving current extinctions. Conservation efforts that ignore its implication will be less effective and even risk prone (Stockwell *et al*., 2003). Recent simulation models show that, within the constraints of the external environment and the genetic potential of their biota, ecosystems can evolve to a state where they are highly resilient to perturbation (Cropp and Gabric, 2002). Thus, if contemporary evolution is an important source of ecological and co-evolutionary dynamics in natural biological communities, the preservation of ecosystems will require the preservation of long-term evolutionary processes (Cardinale *et al*., 2002).

In environments that have a long history of grazing, such as the Mediterranean ecosystem, grazing is considered essential to the maintenance of species diversity (Grime, 1979; Crawley, 1983; McNaughton, 1985; Milchunas *et al*., 1988; Noy-Meir *et al*., 1989), although high stocking rates or grazing in poor soils (arid or very saline) can decrease plant diversity (Milchunas *et al*., 1988; Hobbs and Huenneke, 1992; Olff and Ritchie, 1998). In traditional grazing ecosystems, grazing can affect the system in two opposing directions: a) by reducing ecosystem diversity, especially in poor soils, and b) by increasing diversity and productivity of the ecosystem, particularly in natural ecosystems or under low grazing pressure in rich ecosystems. The relationship between grazing impact and ecosystem function is complex and not well understood. We need precise tools to determine when disturbance exceeds the threshold of tolerance (resistance and resilience), and thus drastically changes ecosystem structure and function causing it to switch from one steady state to a new one (Holling, 1973).

In this study, we assessed the effect of long-term grazing on vegetation by analyzing the disturbance gradient at increasing distances from the source. Disturbance is most intense near shelters and watering points, which produces a gradient of soil surface disruption, compaction, and changes in the composition and cover of perennial vegetation (Nash *et al*., 1999). Our objective was to detect long-term structural changes or drift in the ecosystems by characterizing the parameters resulting from the dynamic variation of the system, before it is too late to prevent irreversible degradation.

Study Areas

Four characteristic ecosystems of the Mediterranean region were selected. In the shrubland of Greece, we selected the village community of Sykia (14 060 ha) on the Sithonia Peninsula (Greece). The climate is sub-humid Mediterranean with mild winters. The geological bedrock is mainly metamorphic rocks of the Mesozoic Era, with some sites covered by sedimentary rocks. The rangelands covered 11644 ha, with 9499 ha shrubland of broadleaved evergreen species or maquis dominated by *Pistacia lentiscus*, *Olea europea*, *Erica* spp., *Cistus* spp., *Quercus ilex*, *Q. coccifera* and *Arbutus unedo*.

A semi-arid matorral was selected in southeastern Spain in Cabo de Gata Natural Park (37 570 ha), where the elevation ranges between sea level and 493 m at El Fraile Peak. This area has been preserved since 1987. The climate is Mediterranean semiarid. The middle dense matorral of *Chamaerops humilis*, *Rhamnus* spp. and *Periploca laevigata* occupies 9332.41 ha (24.21% of the park area), and the Steppe grassland (*Stipa tenacissima* with *Phlomis*, *Thymus* and *Sideritis* as dominant species) occupies 10555.20 ha (27.4% of the park area). This study was performed in the middle dense matorral of the Sabinar-Romeral site.

In the high mountain grasslands located in the Çamliyayla (Namrum) Region of the Taurus Mountains, Turkey, we selected the Sigiryaylasi area located at 1300-1400 m a.s.l. It includes about 220-250 ha of pastureland and a typical temperate sub-humid Mediterranean climate. The characteristic vegetation is a low scattered matorral of *Phlomis* and grassland colonized by terophytic and ruderal plants.

Finally, we selected a high mountain grassland at Ait Beni Yacoub, Middle Atlas, Morocco, which occupies 13429 ha of rangelands. The characteristic vegetation is a low scattered matorral of *Genista* sp. and *Thymus* sp. colonized by *Poa* sp. grassland.

Livestock feeding habits and rangeland management

Grazing management in the dense matorral of the Sithonia Peninsula, northern Greece (Toroni, Chalkidiki) and in the semi-arid matorral of Cabo de Gata, Spain, involved use by individual shepherds holding grazing rights. The animals (goats in Greece and sheep and goats in Spain) moved daily from the shelter to different parts of the rangeland, which produced a gradient of soil and vegetation disturbance from the shelter to the periphery. The two high mountain grasslands in Ait Beni Yacoub, Middle Atlas, Morocco, and the Çamliyayla (Namrum) Region of the Taurus Mountains, Turkey, were nomadic and common lands.

Effective stocking rate (ind. ha^{-1} $year^{-1}$) was calculated by direct observations (Table 1). Animal movements (sheep and goats) were located using GPS and transferred to a map in GIS format (Geographical Information System). Effective stocking rate was calculated by multiplying the average stocking rate by a correction factor of rangeland use. In the Turkish study areas, effective stocking rate was calculated based on biomass production in exclosures compared with the biomass outside the exclosures, and then compared with the average ingested feed of an adult sheep.

In each study area, a grazing gradient was established across increasing distances from a water point (for the nomadic herds) or from a shelter (for the established herds). In Sithonia (Greece) and Middle Atlas (Morocco), we identified three levels of grazing pressure (low, medium and high). In Cabo de Gata (Spain), a control (no grazing) treatment was also added. In the Taurus Mountains (Turkey) only medium and high levels of grazing pressure were observed.

GRAZING PRESSURE AND CHANGES IN PLANT DIVERSITY AND FREQUENCY

We recorded 96 vascular plant species in Sithonia, 144 in Cabo de Gata (at the Sabinar-Romeral site), 130 in the Taurus Mountains, and 95 in the Middle Atlas study area. At most sites, there was a significant decrease in the total number of species with an increase in grazing disturbance (Table 1), except in Sithonia shrubland, where there was non-significant variation in plant diversity because species sensitive to grazing disturbance (*Quercus coccifera, Olea europaea* var. *sylvestris*) were replaced by grazing-resistant species (e.g., *Plantago* spp. and *Poa bulbosa*). Overall, biodiversity decreased along the sclerophyllous Mediterranean ecosystems from the highly dense matorral to the low scattered matorral and to the xeric grassland, being more drastic towards the end of the regressive successional stage of each community (Figure 1). In addition, we observed that a diverse community also exhibits a high evenness index. Plants tended to be equally represented (larger evenness index) in the lightly grazed areas than in heavy grazed areas. Under heavy grazing pressure, a few species dominated the community according to the appearance of grazing-resistant species.

The increase in plant cover heterogeneity (low evenness) with increasing grazing disturbance confirmed the trend for an increase in grazing-resistant plants, which eventually become dominant. For example, cushion perennial grasses with underground stems (e.g., *Stipa tenacissima*) with their buried buds, are more protected from grazing than are shrubs. Thus, the Cabo de Gata middle dense scrubland of *Chamaerops, Rhamnus* and *Periploca* has transformed into *Stipa* steppe at the end of the regressive succession.

In the shrubland of the Sithonia Peninsula, where more species adapted to high disturbance (*Cistus monspeliensis*) than species that indicate pristine matorral, such as *Quercus coccifera* and *Olea europaea* var. *sylvestris*, that become very scarce as grazing pressure increases. Species exhibiting grazing syndrome (prostrated or rosette twigs), such as *Plantago* spp., also became very frequent. In the Middle Atlas grassland, *Poa bulbosa* dominated under heavy grazing, while *Genista* sp. decreased. In the Taurus Mountains, grassland and shrubland differed significantly in bareground cover and species richness, although no significant difference were observed in proportional diversity indices.

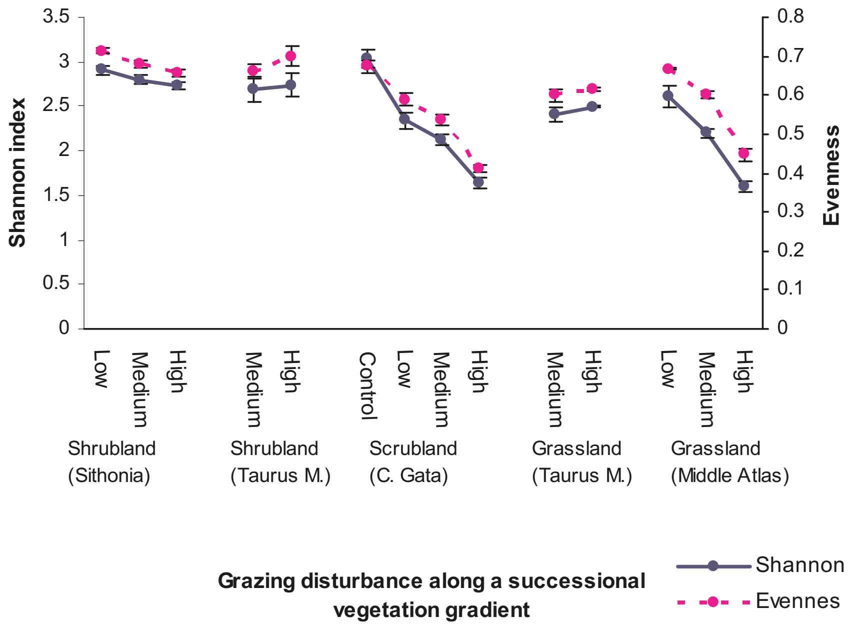

Figure 1. Changes in Shannon Diversity and Evenness indices along the grazing disturbance gradient in five Mediterranean ecological communities

Table 1. Effective stocking rate (ind. ha-1 year-1 using the study area), richness (average number of species ± SE), percentage of bare-ground, and mean ± SE of the Inverse Simpson Index calculated from the presence of species along the three transects per test area. F values were calculated using a one-way ANOVA with grazing pressure as fixed-effect factors. * P< 0.05, ** P < 0.01, *** P < 0.0001.

Grazing pressure	Effective Stocking Rate	Richness	Bareground cover (%)	Inverse Simpson' Index
Shrubland of Sithonia Peninsula (Greece)				
Low	0.3	59±2.6	4.4	9.59±0.51
Medium	2.6	61.7±0.3	16.4	7.69±0.65
High	8.2	62.3±0.9	21.5	7.62±0.33
		$F_{2, 6} = 1.18$	G = 489.3***	$F_{2, 6} = 4.73$
Scrubland of Cabo de Gata (Spain)				
Control	0	89.7±4.5	20.9	9.25±0.50
Low	0.27	53±2.9	34.6	4.70±0.35
Medium	0.46	51.66±3.3	31.5	4.32±0.26
High	0.65	54±4.6	29.1	2.24±0.10
		$F_{3, 12} = 22.52$ ***	G = 115.9***	$F_{3, 12}$=77.11***
Grasslands of the Middle Atlas (Morocco)				
Low	0.9	61.5±4.5	9.4	7.80±0.49
Medium	1.54	44.5±0.5	21	5.14±0.17
High	2.49	36±0.99	20	3.10±0.13
		$F_{2, 4} = 33.38$**	G = 171.9***	$F_{2, 6} = 58.76$
Shrubland & Grassland of Taurus Mountains (Turkey)				
Med_Grassland	4.4	59±2.1	11.1	5.94±0.50
High_Grassland	5.2	55.7±4.7	6.6	6.19±0.76
Med_Shrubland		58±5.3	32.3	7.16±0.81
High_Shrubland		50.7±3.3	35.9	8.78±1.51
		$F_{3,11} = 1.06$	G=1393.0***	$F_{3,11} = 1.06$

Fractal Dimension of Plant Spatial Patterns

Spatial patterns have an important effect on ecosystem function. Soil erosion and runoff distribution is directly related to the spatial distribution of the vegetation (Cerdá 1997a, Sole Benet *et al.*1997, Martinez Mena *et al*. 2000).

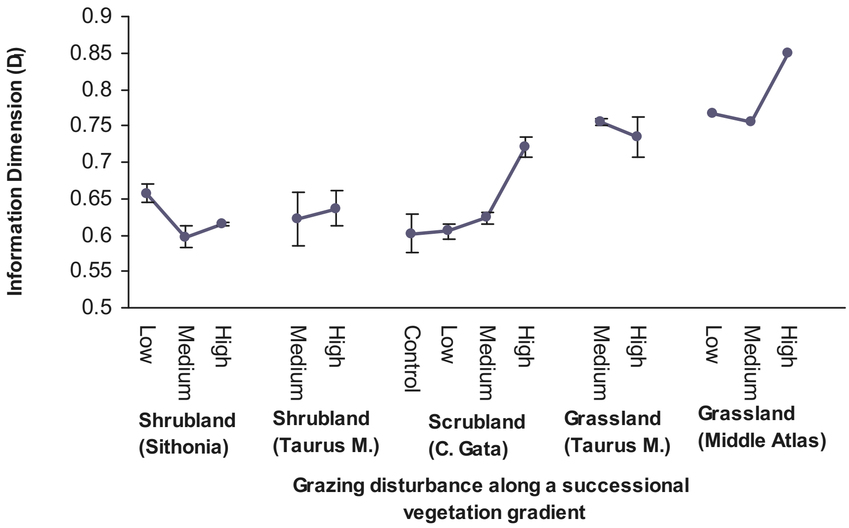

Figure 2. Changes in Information Fractal Dimension D_I along the grazing disturbance gradient in five Mediterranean communities. The Information Fractal Dimension $D_I \cong \lim_{\varepsilon \to o} \frac{H'(\varepsilon)}{\ln 1/\varepsilon}$ (Alados *et al*. 2003) is calculated by regressing the Shannon Index $H'(\varepsilon)$ against the natural logarithm of window size ε. The slope of the line is the Information Fractal Dimension.

Plant spatial patterns can be quantified using the fractal dimension. In this study, we calculated the change in the Information Fractal Dimension along the regressive successional vegetation stages of different plant communities. The Information Fractal Dimension measures the complexity of a system, independent of the scale of observation, over a range of scales (Farmer *et al*., 1983; Alados *et al*., 2003). Changes in the fractal dimension indicate a substantial change in the processes that generate plant spatial patterns (Krummel *et al*., 1987; Li 2000) and can be used to measure the degree of regression of vegetation succession (Alados *et al*., 2003, 2004). The Information Fractal Dimension provides a quantitative measure of the degree of patchiness of the plant community independent of scale. It increases with the degree of randomness (lack of spatial correlation).

We observed that the fractal dimension declined from a dense matorral to a discontinuous matorral, but increased from a discontinuous matorral to a scattered matorral, and kept increasing towards grassland. That change in the fractal dimension indicates a substantial change in the processes that generate plant spatial patterns. The "passage" from the matorral climax (high and dense) to low and discontinuous matorral occurs as a result of degradation, mainly due to overstocking, burning and cutting, and can be used to quantify degradation stages of the Mediterranean-type ecosystem.

Spatio-temporal heterogeneity is not the result of random processes; rather, it is a functional ecosystem property (Wu *et al*., 1985, Couteron and Lejeune, 2001; Rietkerk *et al*., 2002), that affects ecosystem functioning (Pickett and Cadenasso, 985; Hutchings and Wijesinghe, 1997). To develop conservation strategies it is crucial to understand the self-organizing capacity of the system. Self-organized instability theory proposes that ecological complexity results from the interaction between the trend to increase diversity as the ecosystem develops and the negative feedback that arises from interactions among individuals (Solé *et al*., 2002). That results in two opposite processes (interaction declining with ecosystem development, and immigration increasing with degradation) in a common pattern, i.e., small patches homogeneously distributed in the landscape (Alados *et al*., 2004). In our study, we observed the same pattern in both extremes, the better preserved and most degraded, which confirmed previous hypotheses.

Since different species have different roles in ecosystem functioning, and not all of the species are expected to exhibit the same trajectory, we tested whether and how the spatial aggregation of each species' cover changed, independently of the scale of measurement. Detrended Fluctuation Analyses (DFA), developed by Peng *et al*. (1992), and applied to plant spatial analyses by Alados *et al*. (2003, 2004), can be used to quantify the degree of organization of each plant species. DFA corresponds to standard spectral analysis (Wilson and Francis, 2003). It measures the level of autocorrelation (α) of a random walk generated from the sequence of presence and absence intercepts per each species along the transect.

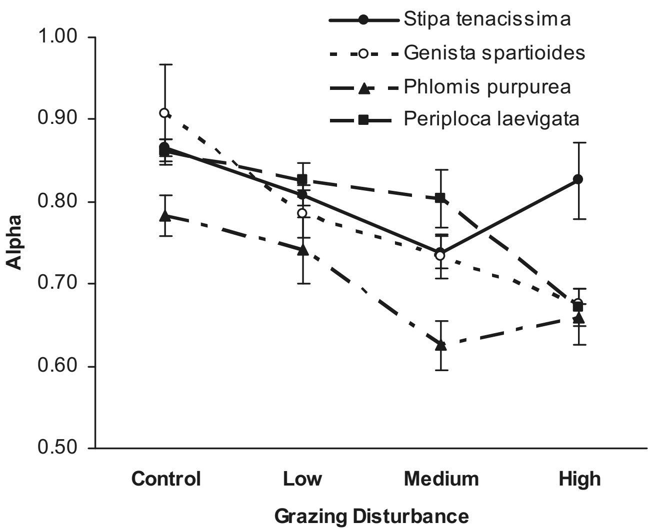

Figure 3. Changes in alpha exponent versus grazing disturbance for the characteristic species of Cabo de Gata NP. Alpha is calculated from the residual variance of the regression of $y_b(s)$ on s per non-overlapping boxes of size from the N point contacts in the transect:

$$F^2(b) = \frac{\sum_{s=1}^{N}\left(y_b(s) - \hat{y}_b(s)\right)^2}{N}$$

The slope of the line relating F (b) to b determines the scaling exponent α: F (b) $\propto$ b$^{\alpha}$ The scaling exponent alpha is inversely related to the fractal dimension

The extent to which plant spatial patterns depart from randomness is expected to increase with community age. During early colonization, the plant distribution is expected to be ramdom (Kershaw, 1963; Fowler, 1990), then, the interactions among components increase and the system moves away from stochasticity and towards spatial organization. In our study, α was lower in the less competitive species (annuals) and larger in the more competitive species (shrubs), which suggests that the lower competitors are affected by the stochasticity of their colonization and mortality, in addition to the stochasticity of the mortality of their best competitors (Alados *et al*. 2003, 2004).

We considered how the positive feedback from facilitation processes can lead to self-organized vegetation patterns in arid ecosystems as the ecosystem develops, as opposed to the random patterns that arise from competitive interactions of colonizing species in disturbed habitats. To that end, we analysed the change in spatial organization along a gradient of degradation. The spatial organization of the characteristic plants of each community increased in the best preserved areas (Figure 3 and 4). In contrast, as grazing pressure increased, those plants become more randomly distributed, except for species typical of perturbed ecosystems, whose spatial organization increased (e.g., the alpha autocorrelation parameter of *Euphorbia* in the Middle Atlas grasslands increased from 0.60 to 0.77; Alados *et al*., 2004).

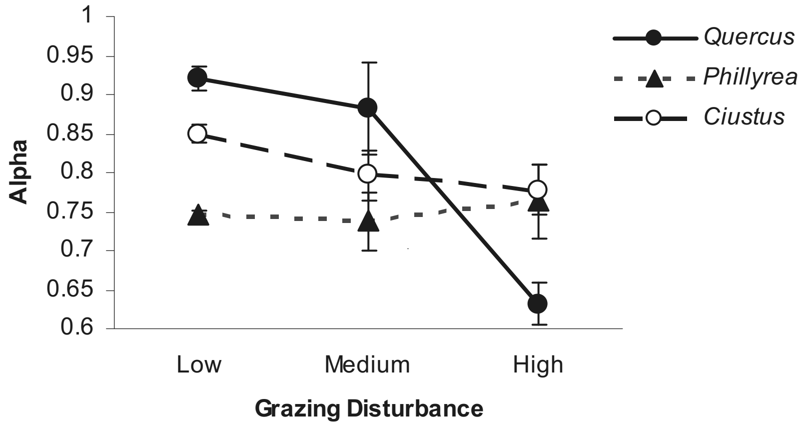

Figure 4. Changes in alpha exponent versus grazing disturbance for the characteristic species of Sykia shrubland (Greece)

In addition, the degree to which randomness increased with grazing disturbance was related to the sensitivity of the species to grazing. For example, *Chamaerops* declined in frequency, but its spatial organization did not change because its renewal buds are buried and not accessable to livestock. Similarly, the renewal buds of *Phillyrea latifolia* could not be accessed by the goats, so it was also very resistant to heavy grazing. *Stipa* *tenacissima* has extensively branched rhizomes that fragment by withering and expand over large areas (Hessen 1999). The buried renewal buds of *S. tenacissima* cannot be reached by livestock and have a high capacity to retain soil and runoff, especially in fine material soils (Sánchez and Puigdefábregas, 1994; Cerdá, 1997b; Cammeraat *et al*., 2002). In addition, the low palatability of *S. tenacissima* favours development under grazing pressure. We observed that the spatial organisation of *S. tenacissima* did not change with increased grazing pressure. On the contrary, the spatial organisation of sensitive species of the pristine matorral community, such as *Q. coccifera, O. europaea var. sylvestris, Erica. arborea, Phlomis purpurea* and even the grazing tolerant *Periploca laevigata* decreased drastically (Figures 3 and 4).

Thus, the degree of autocorrelation of plant spatial distribution at the species level, and the information dimension at the community level allowed us to quantify the degree of degradation of natural communities and to determine the sensitivity of key species.

PLANT POPULATION STRESS ASSESSMENT

The effect of grazing on vegetation can vary depending on plant strategy and available resources (i.e., plant physiological and evolutionary responses to water stress depend on the range of resources to which the plants are adapted). In addition, the relationship between stress and fitness is not expected to be linear. Plants that have previous exposure to a stress are expected to be better at resisting further stress. For example, plants that experience frequent periods of drought evolve a conservative strategy of reducing growth under severe drought while maintaining homeostasis of fundamental structures for fitness (Chapin, 1991). That conservative strategy has been called “stress resistance syndrome” (Grime, 1979; Chapin *et al*., 1993) and it is frequently found among plants in dry areas (Edelin, 1977; Thomansson 1977). In contrast, plants living in more mesic habitats might have a more competitive strategy in which they allocate more energy to production, while still being able to maintain developmental stability (homeostasis) in growth structures, except in the face of occasional drought periods. Thus, if disturbance is a persisting part of the environment, the ecosystem might develop mechanisms of adaptation to prevalent conditions. For example, palatable plant species that are frequently grazed show lower stress under medium grazing than when not grazed (Escós *et al*., 1997; Alados *et al*, 1998, 2002). Those results are particularly important in

Mediterranean ecosystems, where sustainability depends on human impact and the history of adaptation (Milchunas and Lauenroth, 1993).

Developmental instability represents the cumulative effects of small, random developmental perturbations of environmental origin (Waddington, 1957). It is reflected by exaggerated intra-individual variation in repeated traits and patterns. Developmental instability has the advantage that, as a nonspecific measure of developmental disturbances, it can be used as an early indicator of anthropogenic impacts on animals and plants (Zakharov *et al*., 1987; Graham *et al*., 1993). Traditionally, developmental instability is assessed by measuring fluctuating asymmetry, random deviations from bilateral symmetry (Palmer and Strobeck, 1986). Most studies of plant developmental instability have measured the fluctuating asymmetry of leaves and flowers (see Møller and Shykoff, 1999, for review). Statistical noise in other allometric relationships can also be good indicators of developmental noise (Freeman *et al*., 1993; Graham *et al*. 1993).

Allometric relationships between plant parts are maintained during growth so that the entire structure maintains its mechanical stability, and they are consistent within species (White, 1981; Weller, 1987). One of the most important allometries observed in plants is the arrangement of phyllotaxis around stems. Several studies have shown that the error in the curve-fitting accuracy between internode length (L) and node order (N) fits the equation $L = kN^a e^{-bN}$ (Alados *et al*., 1994, 1998; Escós *et al*. 1995, 1997; Sherry and Lord, 1996; Anne *et al*., 1998; Tan-Kristanto *et al*. 2003) and is a better indicator of developmental instability than is fluctuating asymmetry.

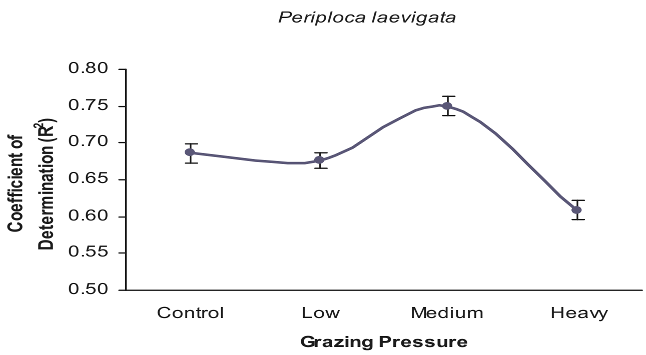

Figure 5. Developmental instability of shoots measures as R^2 of Periploca laevigata

In our study, we analyzed the change in developmental instability of the characteristic species of the community along the grazing intensity gradient. Two dominant shrub species (*Phillyrea latifolia* L., palatable, and *Cistus monspeliensis* L., unpalatable to domestic animals) were studied from Sykia (Sirkou *et al.,* 2002). Grazed *Phillyrea latifolia* was developmentally unstable compared to ungrazed because its degree of leaf fluctuating asymmetry was greater. That was particularly evident when we compared the upper part of shrubs (>1.50 m height) that could not be reached by goats and the lower, accessible area (<1.50 m height). Separate analyses of the upper and lower parts revealed that *Phillyrea* could compensate for the stress produced in the lower part by increasing growth and maintaining developmental stability in the upper, unreachable shoots (Sirkou *et al*., 2002). The fact that grazing, even when it is quite intense, maintains the developmental stability of the top parts of *Phillyrea* shrubs, indicates that this species is very tolerant (even under heavy grazing pressure) and suggests that a compromise must be found between overgrazing and non-grazing in the pastoral management of this species. On the other hand, the translational asymmetry of *Cistus monspeliensis* did not vary significantly among different grazing treatments.

The development of *Periploca laevigata*, a high palatable species from Cabo de Gata (Spain), was more stable under medium grazing, as estimated by translational and floral asymmetry, than under heavier or lighter grazing (Figure 5). *P. laevigata* also responded to grazing pressure by accelerating growth at the beginning of spring, when grazing activity is concentrated in herbaceous plants, and finishing growth sooner than in the other grazing treatments (Alados *et al*. 2002). Indeed, plants with less translational asymmetry grew more and produced more flowers.

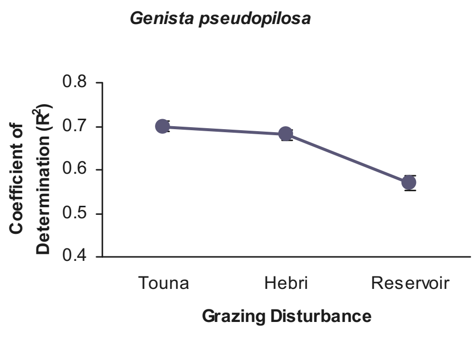

Figure 6. Developmental instability of shoots measures as R^2 of Genista pseudopilosa

Natural selection is expected to favor early growth and reproduction, such that plants phenologically escape herbivores that feed on the plant later in the season. Under high grazing pressure, it would be advantageous for *P. laevigata* to grow and establish reproductive structures before becoming a food source to sheep and goats. Higher photosynthetic activity during such a period would result in a higher capacity to construct carbon structures and permit faster growth. Early in the growing season, ungrazed *P. laevigata* had higher photosynthetic activity than did grazed plants, which suggests that the defoliated plants were still recovering from herbivore damage from the previous period (Castro *et al*. 2003). Later in the growing season, grazed plants had higher photosynthesis activity than did ungrazed plants, which suggests investment in chemical defences (Barroso *et al*., 2003). In Cabo de Gata, *Sideritis osteoxylla* was favored by moderate grazing pressure, as indicated by the larger curve-fitting accuracy of the relationship between internode length and node order shown at intermediate grazing compared to lightly and heavily grazed areas. In contrast, grazing did not have a negative effect on *Thymus hyemalis* or *Teucrium lusitanicum*.

Grazing pressure at the Ait Beni Yacoub of Middle Atlas significantly ($F\ 2.270 = 25.77$, $P < 0.0001$) increased developmental instability of *Genista pseudopilosa*, as measured by the curve-fitting accuracy of the relationship between internode length and node order (Figure 6), which indicates that the grazing pressure reached at this site significantly negatively affects the performance of this species. *G. pseudopilosa* functions as a nursery species by protecting underneath other species from grazing, and the decline of this species clearly is a threat to the maintenance of the diversity in the area.

CONCLUSIONS

Based upon the results of our study, we conclude that the impact of grazing on the preservation of vegetation depends on climatic conditions, soil properties, and vegetation cover. In Sykia (Greece), moderate grazing (2.5 goats $ha^{-1}year^{-1}$) seems to be the proper stocking rate because it combines increased productivity for goats with plant community stability and resilience. In the semi-arid land of Cabo de Gata (Spain), effective stocking rates above 0.5 sheep $ha^{-1}year^{-1}$ threaten the persistence of the tall-brush community and favor a posterior regressive stage in the vegetation towards tall-grass steppes. At Sigiryaylasi (Turkey), a grazing pressure of 4-5 sheep $ha^{-1}year^{-1}$ increased the risk of erosion on sloped terrain, but not in flat areas. In the Ait Beni Yacoub (Morocco), if settlement on rangelands continues as it has in the last five years, grazing pressure will vary from 3.38 to 6.75 sheep $ha^{-1}year^{-1}$ in ten years, which will turn the vegetation into an impoverished grassland of *Poa* spp. and *Carex* spp.

In addition, fractal analysis of plant spatial patterns provided a quantitative characterization of vegetation dynamics in response to disturbance, which can help to predict the effect of grazing independently of scale and determines the sensitivity of key species to grazing disturbance. Drastic changes in the parameters that characterize vegetation spatial patterns revealed important changes in the processes driving the system. In addition, developmental instability analyses of target species will help to detect the effect of environmental stresses and to understand the alternative strategies of the species under specific circumstances.

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USING A GIS FOR SUSTAINABLE USE AND MANAGEMENT OF AN IRRIGATION AREA IN THE SPANISH - PORTUGUESE BORDER THREATENED BY DESERTIFICATION

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ABSTRACT

Inappropriate management of agricultural irrigated land, using excessive amounts of production factors – pesticides and fertilizers in particular – can lead to rapid and irreversible soil degradation and the corresponding decrease in production capacity. The method presented here, applicable to the entire Mediterranean region, was designed to support the sustainable management of a 12540 ha irrigated area located in the Spanish-Portuguese border, with special emphasis on the prevention of desertification. This specific tool, incorporates a data collection from 1428 georeferenced points and respective topsoil samples, describing soil type, depth, slope, drainage, pH, organic matter content, electrical conductivity, exchangeable sodium content, and available phosphorus and potassium. Parameterized maps were prepared for all these soil properties using Geographic Information System (GIS) software to store, manage, analyze, and display the georeferenced information. Predictive maps for organic amendments need were elaborated for use in the sustainable and integrated land management of the area. The higher risk zones were identified on the basis of their soil depth, slope, drainage, organic matter, electrical conductivity, and sodium saturation percentage.

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INTRODUCTION

The “Caia Irrigation Perimeter” is located in a typical Mediterranean zone (in Spanish-Portuguese border – Figure 1), with hot dry summers and wet cool winters (Azevedo, 1998; Sousa, 1999). These climatic conditions strongly constrain agricultural activity. In summer, when the plants have the best conditions of temperature and sunlight for growth and production, the lack of water compromises any possibility of realizing this productivity (Azevedo, 1998). The only way to avoid this problem is by irrigation.

Figure 1. Caia Irrigation Perimeter localization

In the last decades a rapid increase of land conversion into irrigated agricultural systems has occurred. These agricultural systems are far more intensive than the traditional dry-land systems (Aragües & Cerdá, 1998), and result in changes in the soils that include the introduction of larger amounts of herbicides and fertilizers, with the consequent increase in electrical conductivity (Benito, 1991; Passaraki, 1992; Fitzpatrick *et al*., 1994; Miller & Donahue, 1995; Kolganov *et al*., 1996; Ceuppens *et al*., 1997), increase in the mineralization of organic matter, with the corresponding decrease in the soil's organic carbon content (Campbell & Suster, 1982; Dalal & Mayer, 1986; Aguilar *et al.*, 1988; Vera & Romero, 1994), and the leaching of exchangeable bases, leading to a decrease in the cation exchange capacity (Ribamer-Pereira & Sequeira, 1979; Amiel *et al*., 1986; Thellier *et al*., 1990; Falkiner & Smith, 1997) and in the soil pH (Dalal & Mayer, 1986; Schwab *et al*., 1989; Santos, 1996; Lal, 1997).

The salts brought in with the irrigation water, especially sodium salts, lead to a rise in electrical conductivity and in the sodium saturation percentage, severely impoverishing the soil's physical properties (Letey, 1993; Miller & Donahue, 1995; Bioderbeck *et al*., 1996; Porter *et al*., 1999; Morshedi & Samedi, 2000). Moreover, the large amounts of water used cause erosion problems over large areas (Mañas *et al*., 1999; Maticic, 1999; Roman *et al*., 1999; Shepard, 2000; Sties & Kraft, 2000), especially in regions with shallow soils on sloping terrain.

These new agricultural irrigated ecosystems, frequently lead to problems of sustainability (Nunes, 2003). Indeed, large areas of Portugal, which were previously very productive, are today facing significant productivity problems which justifies the Portuguese saying that “Irrigation is the art of enriching the fathers and impoverishing the sons” (Santos, 2003). The result is that the soil is no longer able to maintain farming as an economic activity (Benito, 1991), and since there is little choice of occupation in rural areas, these regions are being abandoned by their inhabitants, with the consequent environmental and social desertification.

The objective of the present work is to design a method and develop a tool both applicable on planning soil management for all Mediterranean regions. To this end, we use a Geographic Information System (GIS) to store, manage, analyze, and display the georeferenced information (Renschler *et al*., 2002; Pakparvar & Abtahi, 2002). Firstly, we make predictive maps for organic restoration and mineral fertilization. The aim is to constitute a tool for sustainable and integrated land management, to prevent future desertification. Secondly, by superimposing in the GIS the different layers containing information on soil characteristics (pH, organic matter, electrical conductivity, useful depth, drainage conditions, and slope), we try to determine which areas of the Caia Irrigation Perimeter are facing higher risk of becoming desertified either because they are already much affected or because they are very vulnerable due to the presence of desertification factors, and are therefore requiring urgent intervention to avoid the complete destruction of their productive potential.

Useful soil depth, slope, and drainage conditions were determined at each one of the 1428 georeferenced sampling points within the study area of the Caia Irrigation Perimeter (12540 ha): topsoil samples were taken at each point for physicochemical analysis. The data were used to estimate the fertility conditions of these soil locations, and thence to elaborate the predictive maps referred previously.

MATERIAL AND METHODS

Collection of soil samples

Firstly, the map of the Caia Irrigation Perimeter (scale 1:25.000), of about 12540 ha overall, was divided into a 10 ha square grid.

For each cell of the grid, the centre of the corresponding polygon was referenced geographically (UTM coordinates). All data collected within that cell would then be associated to the central point.

For those cases in which a cell was found to be heterogeneous, the corresponding polygon was split into two equal polygons in a northerly direction, whose centers were again referenced geographically. This was done to ensure the homogeneity of the reality represented by each sample.

Within each polygon, we collected 10 topsoil (0 – 20 cm) sub-samples in a randomized fashion. These sub-samples were merged to give a composite sample that was taken for physicochemical analysis in the laboratory.

The record for each soil sample was completed with the following information: agricultural system type (dry-land or irrigation), irrigation system used, if any, the usual crop and its yield, its useful depth, drainage conditions, and slope.

Field and analytical methods

Useful depth – each time that a topsoil sample was collected, perforation was continued until an impenetrable layer was encountered. The greatest depth reached was recorded as the useful depth.

Slope – In the centre of each polygon, the slope was determined with a clinometer’s, looking north.

Drainage conditions – This parameter was determined indirectly by the observation of hydromorphic symptoms at different depths.

For the physicochemical assays, each soil sample was air-dried and then sieved through a 2 mm sieve before analysis.

pH – Determined with a potentiometer in a 1:5 (v/v) soil-water suspension according to the Manual for Soil and Water Analysis (1996), method A04.

Electrical conductivity – Determined with a conductivity meter in a 1:5 (v/v) soil water suspension according to Rhoades (1982).

Organic matter – Determined by oxidation with potassium dichromate according to Nelson and Sommers (1982, 1996) and USDA (1996).

Available phosphorus and potassium – Extraction with an acetic acid and ammonium lactate solution at pH 3.65-3.75 according to the Egner-Riehm method (Riehm, 1958).

Exchangeable cations and cation exchange capacity – Extraction with triethanolamine and barium chloride at pH 8.2 according to the Mehlich method (Mehlich, 1948).

Maps

All maps, including the predictive maps for the most vulnerable zones, were prepared with the Geographic Information Systems program ArcView (version 3.2).

RESULTS AND DISCUSSION

Brief characterization of the Caia Irrigation Perimeter

The Caia Irrigation Perimeter is located within the administrative townships of Elvas and Campo Maior, at the confluence of the River Caia with the River Guadiana, in a border zone between Portugal and Spain.

Geology

The geology consists essentially of Cambrian and Silurian formations, with some small eruptive zones associated with hyper-alkaline and alkaline rocks (Nunes, 2003).

Soil

The most common soil groups are, fluvisols (42.7%), luvisols (21.7%), calcisols (16.1%), vertisols (1.8%), regosols (0.6%), and cambisols (6.1%) (Nunes, 2003), (FAO, 1999)

Climate

The climate data was obtained at the Elvas meteorological station, located at 38°53’ N and 7°9’ W, from 1970 to 2002. Potential evapotranspiration is greater than rainfall from April to October, leading to arid conditions. Most of the 483 mm of average annual rainfall coincide with the coolest temperatures from October to March when ETo is lower, leading to an excess of water in the soil.

Crops

The most important crops are: maize (*Zea mays*) for grain production occupying almost half of the cultivated area (49%), wheat (*Triticum aestivum*) (17%), sunflower (*Helianthus annuus*) (7%), tomato (*Lycopersicum esculento*) (6%), and olive (*Olea europea*) (4%).

Parameters analyzed

Local Parameters

Useful Depth

Most of the soils (66.1 %) have a useful depth greater than 100 cm, a value that is considered sufficient for most crops. Soils with a useful depth less than 50 cm represent only a small area (6.1%), and the remaining 27.7 % have a useful depth between 50 and 100 cm.

These results show that erosion is not yet a major problem. There are two possible explanations. Firstly, as will see below, the study area is very flat so that soil runoff is infrequent. Secondly, sprinkler irrigation is the technique most commonly used in this region, so that the amounts and intensity of water applied are easily controlled and hence problems of erosion are rare. This is confirmed by the observation that soils with a useful depth of less than 50 cm are mainly located in the eastern part of the study area. This zone is farthest from the Caia and Guadiana rivers (Figure 2), and has the greatest slopes. Because of its reduced production potential, it is currently used for less demanding crops without irrigation.

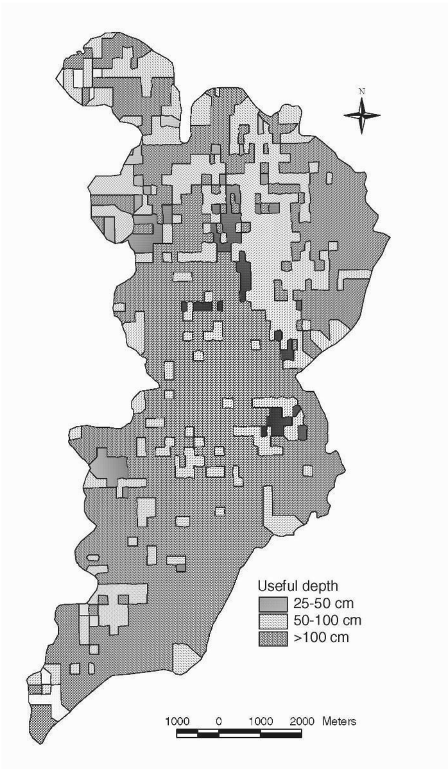

Figure 2. Useful-depth distribution map of The Caia Irrigation Perimeter

Slope

The Caia Irrigation Perimeter is almost flat, with slopes less than 3% in 80.7% of its area and slopes greater than 5% in only 2.6% of the area. This is due not only to the geographical characteristics of the Caia region, located near the Caia and Guadiana rivers, but also to the leveling of the terrain by farmers during the 35 years of existence of the Irrigation Perimeter.

The greatest slopes are located in the eastern part of the study area (Figure 3), coinciding with the regions of least useful depth. Only a small proportion of this land is irrigated, using irrigation techniques that require pumping. It is one of the zones that is most susceptible to erosion, and therefore to desertification.

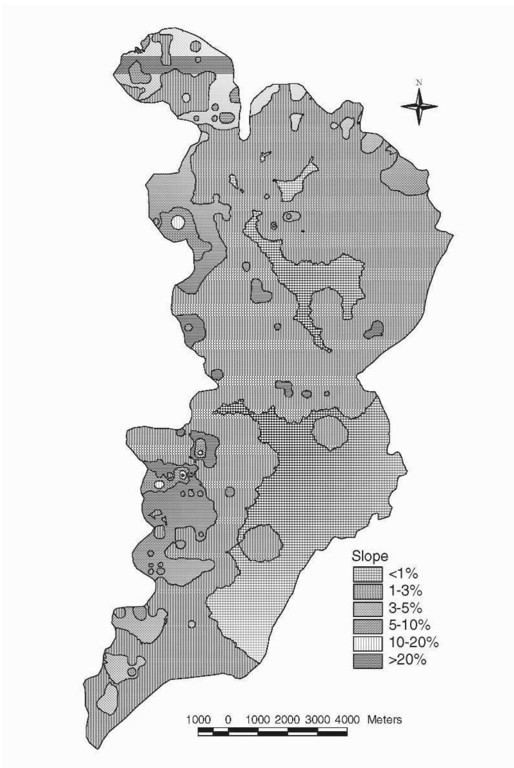

Figure 3. Slope distribution map of The Caia Irrigation Perimeter

Drainage Conditions

In general, the drainage conditions are good. Only 0.2 % of the area has poor drainage with a high risk of waterlogging and consequent runoff.

One sees from Figure 4 that the locations of weak to moderate drainage areas correspond to small valleys and old stream beds.

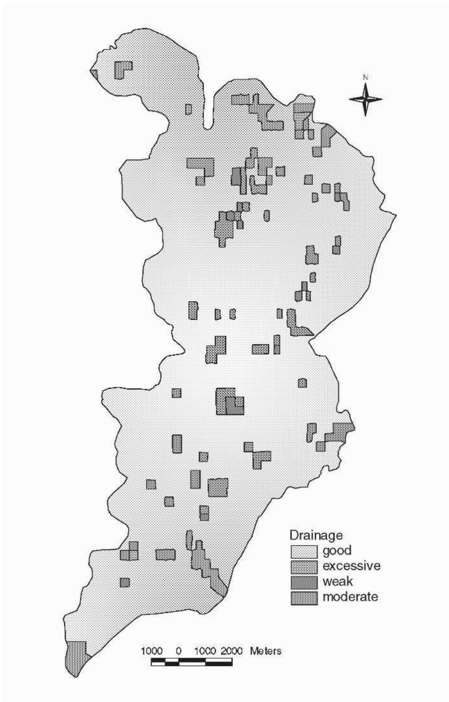

Figure 4. Drainage distribution map of The Caia Irrigation Perimeter

Physicochemical parameters

pH

Over one third of the soils have a near-neutral pH between 6 and 7 (38.6%), and a similar area corresponds to slightly alkaline soils with pH between 7 and 8 (38.3%). The remaining soils, occupying 23.1% of the study area, have slightly acidic characteristics with pH between 5 and 6. No soils were classified as very acidic (pH<5) or very alkaline (pH>8).

With respect to the spatial distribution of the pH values (Figure 5), one observes that most of the acidic soils are located near the Caia and Guadiana rivers. This may be because these zones have been under irrigation for a longer time, and according to Rechcigl *et al*. (1985), Ribamar-Pereira & Cordeiro (1987), Foth (1990), Porta *et al*. (1994), and Miller & Donahue (1995) irrigation is one of the major factors leading to soil acidification. On the contrary, the alkaline soils are located in the west and southwest of the study area, the zones farthest from the Caia and Guadiana rivers. This was the last zone to be irrigated and therefore the least subjected to this acidification process; it is also a zone where calcareous rocks are frequent so that it is normal that soils originating from these rocks should be alkaline.

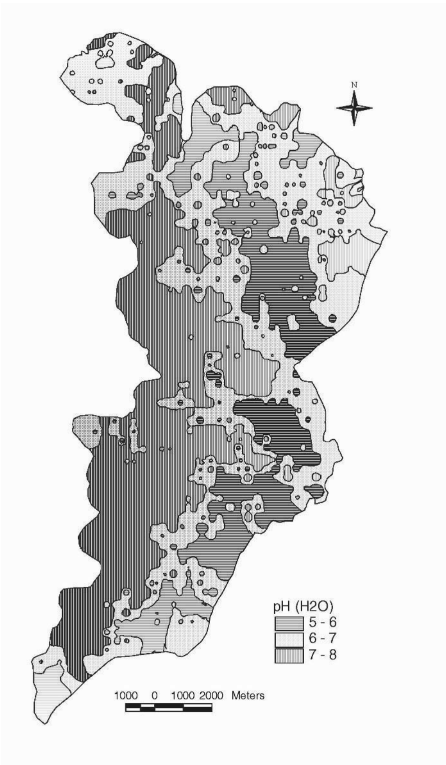

Figure 5. pH (H_2O) distribution map of The Caia Irrigation Perimeter

Electrical Conductivity

Almost the entire region (90.2%) presents very low levels of electrical conductivity (EC) (<0.25 dS m^{-1}), with only 1.9% of the study area having EC values above 0.50 dS m^{-1}.

With respect to the spatial distribution of EC values in Figure 6, the greatest conductivities correspond to small patches scattered throughout the study area, but with a tendency to cluster close to the Caia and Guadiana rivers, and thus coinciding with the zones that have longest been under irrigation (Ferreres, 1983; Papadopoulos, 1988; Benito, 1991; Fitzpatrick *et al*., 1994). These zones have had the most intensive agricultural use, and hence have received the greatest amounts of fertilizer which, according to Passaraki (1992), Fitzpatrick *et al*. (1994), and Santos (2003), may be responsible for higher values of EC.

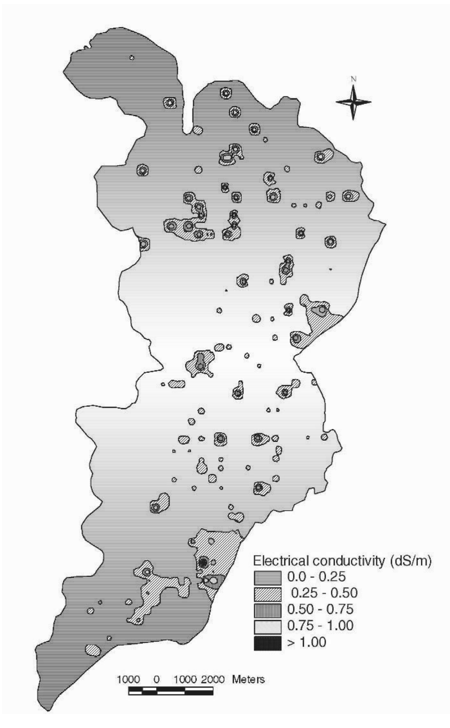

Figure 6. Electrical-conductivity (dS m^{-1}) distribution map of The Caia Irrigation Perimeter

Organic Matter

As was noted above, most of the Caia Irrigation Perimeter soils have low or very low levels of organic matter. This is a common characteristic of Mediterranean soils (Santos, 1996). Only 6.9% of the soils have an organic matter content above 2%, whereas 15.1% of the soils have organic matter levels below 1%, and 65.2% have levels below 1.5%.

The lowest organic matter levels are found near the Caia and Guadiana rivers (Figure 7). The explanation is obvious, since humidity is essential for the mineralization of organic matter, especially during the hot dry summer in Mediterranean regions, and it is therefore to be expected that zones near water have lower levels of organic matter (Miller & Donahue, 1990; Omay *et al*., 1997). Moreover, in the present study area the zones bordering the rivers were the first to be irrigated and hence to undergo increased mineralization due to the presence of water during the normally dry Mediterranean summer (Vera & Romero, 1994; Santos, 1996; Sequeira, 1997).

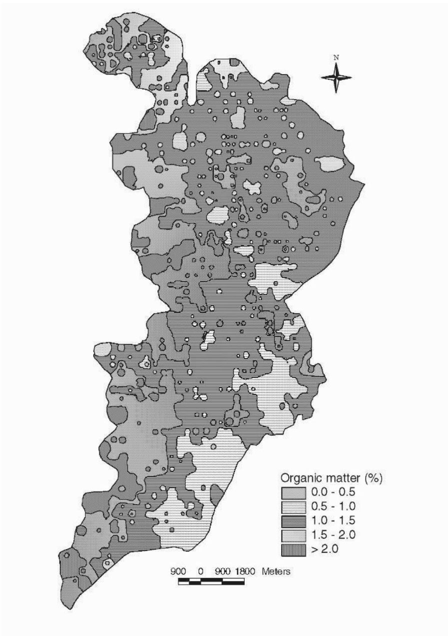

Figure 7. Organic-matter (%) distribution map of The Caia Irrigation Perimeter

Available Phosphorus and Potassium

The Egner-Riehm soil classification method is based on the soil's phosphorus (P) and potassium (K) content. If the soil has a P or K content below 25 mg kg^{-1} it is classified as very poor; if it has a P or K content between 25 and 50 mg kg^{-1} it is classified as poor; if it has a P or K content between 50 and 100 mg kg^{-1} it is classified as medium; if it has a P or K content between 100 and 200 mg kg^{-1} it is classified as rich; and if it has a P or K content above 200 mg kg^{-1} it is classified as very rich.

The P and K concentrations in the soil do not result exclusively from natural processes. Indeed, the levels found in the study area are almost entirely due to the anthropogenic addition of these two nutrients as fertilizers.

Most of the Caia Irrigation Perimeter soils are well provided with available phosphorus: 73.5% have high or very high levels of this nutrient, and only 3.7% have low or very low levels.

Similarly, 94.4% of the soils have high or very high levels of K, and only 0.1% have low levels.

The different P concentration classes are scattered fairly randomly throughout the study area (Figure 8). The distribution of the K concentration classes is similar, except for the fact that one observes a tendency for the lowest values to cluster around the Caia and Guadiana rivers (Figure 8). The explanation may be twofold. Firstly, these are the zones of most intensive agricultural activity, and would therefore have the greatest K consumption, with a consequent lowering of the concentration of this nutrient in the soils. Secondly, these are the soils with the lowest organic matter which, together with their more sandy texture as is usual in river margins, can lead to a lower cation exchange capacity and hence a greater loss of K by leaching.

Using a GIS over this data, one could establish for any zone in the study area the precise requirements of phosphorus and potassium that would have to be applied to ensure full growth and production requirements of a given crop knowing its potential productivity. This would avoid the pollution problems associated with the application of excess nutrients, and hence contribute to a more sustainable land use and the prevention of desertification.

Figure 8. Phosphorus (left) and potassium (right) distribution maps of The Caia Irrigation Perimeter

Exchangeable Sodium and Exchangeable Sodium Percentage

The average soil sodium content in the Caia Irrigation Perimeter is generally very low (Figure 9): 96.5% of the area has an exchangeable sodium level below 0.50 $cmol_{(+)}\ kg^{-1}$, while only 0.2% has a sodium level above 1.00 $cmol_{(+)}\ kg^{-1}$. This is a particularly important finding because, as is well known, high levels of exchangeable sodium can lead to severe deterioration of the soil physical characteristics, as often occurs under prolonged irrigation (McKenzie *et al*., 1991; Letey, 1993; Curtin *et al*., 1994; Bioderbeck *et al*., 1996; Morshedi & Samedi, 2000).

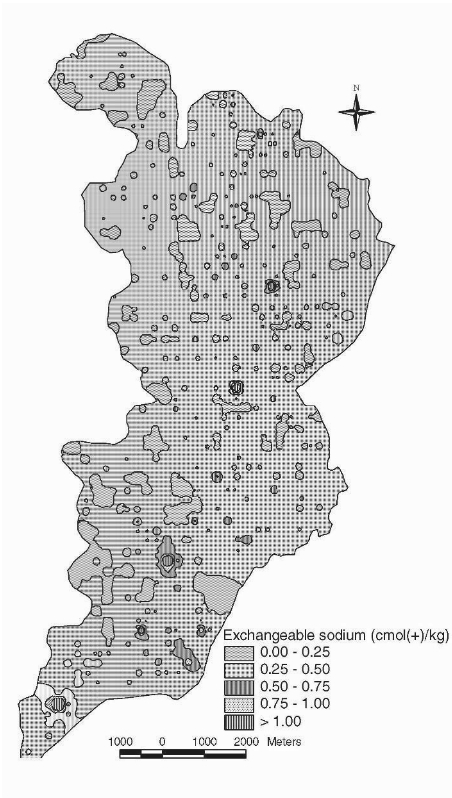

Figure 9. Exchangeable-sodium ($cmol_{(+)}$ kg^{-1}) distribution map of The Caia Irrigation Perimeter

With respect to the exchangeable sodium percentage (ESP), most of the study area (67%) presents ESP values below 5%, and only 5.5% of the area presents values above the 10% threshold described by Shainberg & Letey (1984) and Curtin *et al*. (1995) as being harmful to the soil physical properties. Knowledge of ESP is very important in identifying the zones that are most vulnerable to the processes of desertification in an area of irrigation since this is one of the parameters that is most sensitive to soil degradation and is also a good indicator of potential soil erosion.

The highest values of ESP are found throughout the study area (Figure 10), but again are clustered in the older irrigation area close to the Caia and Guadiana rivers.

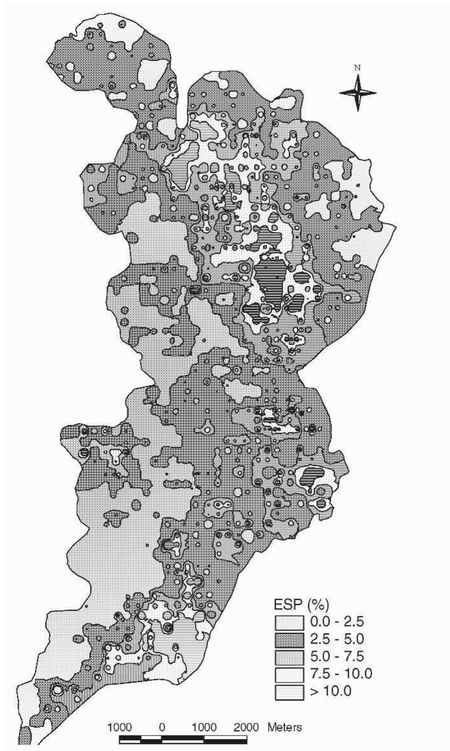

Figure 10. Exchangeable-sodium-percentage (%) distribution map of The Caia Irrigation Perimeter

Organic matter soil amendment

Figure 11 shows the map of the organic soil amendments needed to raise the organic matter levels to values of around 2%, thereby contributing to a more sustainable use of the land.

The organic soil amendment requirements were divided into 6 classes. The first includes soils which already have more than 2% organic matter; they represent only 6.9% of the study area. The second includes soils needing an organic soil amendment of between 0 and 5 t ha^{-1} which represent 5.3% of the study area. Soils in the third class need an amendment of between 5 and 10 t ha^{-1} and represent 9.7% of the study area. The fourth class soils need an amendment of between 10 and 15 t ha^{-1} and represent 10.9% of the study area. The fifth class soils need an amendment of between 15 and 20 t ha^{-1}. The sixth class soils need an amendment of more than 20 t ha^{-1} and represent 60.5% of the study area. These findings confirm what was noted above, that most soils of Mediterranean regions, mainly if irrigated, have low or very low levels of organic matter, this being one of the major desertification risk factors of these regions (Santos, 2003).

One observes in Figure 11 that the eastern and central zones of the study area, which are those of the most intensive agricultural use and longest irrigation history, present the greatest organic matter deficits.

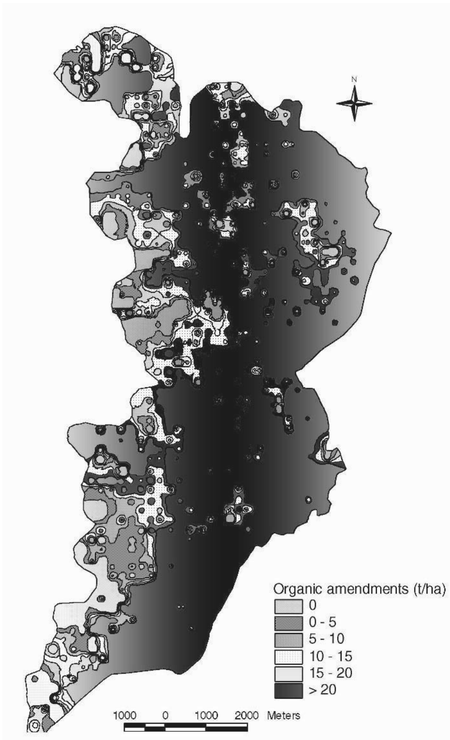

Figure 11. Organic-soil-amendments distribution map of The Caia Irrigation Perimeter

Vulnerability to desertification

The main goal of the present work was to present a method using properties of the topsoil to identify the areas most vulnerable to desertification. For these 1428 points of the Caia Irrigation Perimeter, we marked as most vulnerable to become desertified those with the following characteristics: ESP>10%; useful depth<50 cm; slope>3%; drainage–weak; EC>1.0 dS m^{-1}; or organic matter <1.0 %. We also marked as zones with medium vulnerability to desertification those with the following characteristics: ESP>7.5 and<10%; useful depth>50 cm and<100 cm; slope>3% and <5%; drainage–weak; EC>0.5 and<1.0 dS m^{-1}; or organic matter>1.0 and<2.0%.

With these criteria, only 33.2% of the Caia Irrigation Perimeter area is “not vulnerable to desertification”, whereas 40.3% of the area is at high risk to become desertified in a short period of time. Great care is required with agricultural activities in these high risk zones, the ones that we consider to be “most vulnerable to desertification”, since any mistaken decision, such as the use of excess water during irrigation, soil tillage during a rainy spell or cultivating the soil along the greatest slope, leaving the soil with no plant cover during winter, or even the use of excessive amounts of fertilizer, can cause an irrecoverable loss of productivity and consequent desertification. The zones with a medium desertification risk correspond to 26.4% of the study area. These require some care in their exploitation to avoid the mistakes that we observed in the study area of using excessive irrigation water and too frequent and harsh tillage.

As can be seen in Figure 12, there are three zones of high risk to become desertified. One is located in the north-central part of the study area, and coincides with terrain bordering the River Caia. A second is in the south-eastern part of the study area, and borders the west bank of the River Guadiana. The third is in the west, and coincides with the zones of greatest slopes. The explanation of the high desertification risk in the first two zones can be attributed to irrigation, since these are the zones where irrigation agriculture has the longest history and is the most intensive, with water being applied in large quantities leading to cases of severe runoff, and problems of sodicity and salinity. On the third zone the risk of desertification is a consequence of the greater slopes which increase the risk of runoff if these lands are used for irrigation agriculture.

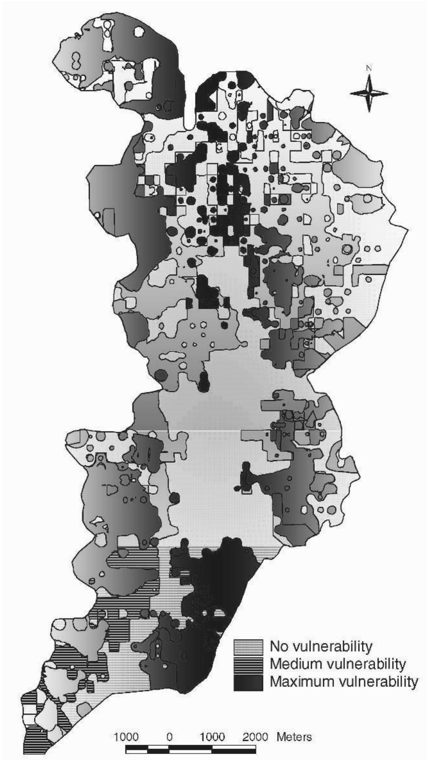

Figure 12. Vulnerable-zones distribution map in The Caia Irrigation Perimeter

CONCLUSIONS

Several conclusions can be drawn from the results of the present work. The study area, an irrigated-farming region in the Spanish-Portuguese border, has characteristics typical of the Mediterranean region – a semi-arid climate with the rainy season in winter and a hot dry summer. Given these conditions, it was possible to establish a method for delimiting the zones that are vulnerable to desertification based on collected topsoil information (useful depth, slope, drainage, pH, EC, organic matter, available phosphorus and potassium, exchangeable sodium, and ESP). Moreover, with the aid of a GIS it was possible to use this same information to draw up maps of organic and/or mineral fertilizer soil amendments, thereby contributing to a more sustainable use of the land and to the prevention of desertification.

In this particular case, we found that 40.3% of the study area could be considered to be very vulnerable to desertification. The most vulnerable areas were found to be those with the most intensive and longest-standing agricultural use, as well as being those with the longest history of irrigation. The main factors responsible for their greater vulnerability were first their low organic matter level and second their greater values of ESP and EC.

We would recommend that the Caia Irrigation Perimeter should be monitored periodically, at least for these three parameters (organic matter, EC, and ESP). According to how they evolve over time, it would then be possible to make informed planning decisions to avoid or mitigate desertification of the zones at high risk, including if necessary the prohibition of agricultural activity or, at least, irrigation, in some zones since, as was shown by the present results, these were the main factors increasing vulnerability. Simultaneously, we would recommend the implementation of an organic soil amendment program, beginning with the zones most lacking in organic matter content, and the development of techniques to enhance the leaching of sodium from the soil and hence reduce the ESP values. These two latter aspects would also be very effective in decreasing the vulnerability to desertification.

A generalization of the application of the method and management tool presented in this paper for regional use through the Mediterranean regions, could not only lead to a better management of agricultural irrigated systems, but also, and more urgent and important, to a reduction of the risk of desertification that many of those areas are facing and, therefore, can lead too an increase in the security of those regions.

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RESTORATION OF BURNED AREAS IN FOREST MANAGEMENT PLANS

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ABSTRACT

Wildland fire is a major disturbance promoting landscape changes and triggering desertification processes in the Northern Mediterranean basin. Addressing that issue in the long term requires both fire prevention and pot-fire restoration measures. Post-fire restoration should mitigate ecosystem degradation, and improve ecosystem regeneration rate and quality.

The impact of wildfires is especially acute in the transition between semi-arid and dry subhumid climates, where dry vegetation fuels facilitate fire spread and water shortage limits post-fire regeneration. In addition, the occurrence of torrential rains produces a high risk of post-fire flash-floods, especially in autumn after summer fires.

The major objectives of post-fire restoration are soil and water conservation and increasing ecosystem resistance and resilience in front of fire. Post-fire restoration strategies are defined according to the degradation stage of the ecosystems and the recovery capacity of vegetation. Plant cover regeneration rate highly influence post-fire soil erosion and flooding risk. The abundance of woody resprouters is recognized in eastern Spain as a critical factor to ensure an efficient recovery of plant cover after fire.

Post-fire restoration planning is addressed taking into account vegetation fragility to wildfires, together with soil erosion risk and soil moisture availability (physical features). Vegetation fragility is defined both in relation to spontaneous regeneration capacity of plant cover and in relation to the ability of keystone woody species topersist after fire. A synthetic indicator to asses wildland protection and restoration priorities in relation to wildland fires is developed by combining vegetation fragility and physical layers in a GIS.

***Desertification in the Mediterranean Region*: *a Security Issue,* 475–488.**
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INTRODUCTION

Semi-arid and dry-subhumid Mediterranean climate zones are subject to desertification processes partly driven by forest fires. Under these conditions, it is necessary to cope not only with the direct effects of the fire but also with the problems of vegetation regeneration caused by inherent water limitations and/or potential impacts from torrential rains; thus, both fire-prevention and burned-area restoration actions may be considered.

When planning these forestry actions it is useful to start with an identification of the most vulnerable areas of the territory in terms of the degradation of the ecosystems affected and their regeneration capacity. For this, two types of strategies can be designed:

> A short-term strategy in which prospecting the burned areas would facilitate both the identification of sensitive zones (with high erosion risk or low regeneration capacity) and the recommendations for urgent actions (emergency seeding for soil cover, reintroduction of resprouting species to provide the ecosystem with greater resilience, etc.).
>
> A long-term strategy at regional scale which identifies the areas most vulnerable to wildfires so that they can be prioritised in prevention and/or restoration activities.

Because of the complex interrelations controlling post-fire regeneration processes, sophisticated models are needed to predict the vegetation response to forest fires (Mouillot *et al*., 2001). Nevertheless, in spite of this complexity, forest planners can carry out an approximation by applying the common procedures in environmental studies: selection of the relevant variables (as well as of the types in which they are divided), and application of metrics (in this case nominal) for integration (MMA, 2000).

The present paper presents the methodology followed in the Valencia Region for evaluating wildland vulnerability to forest fires. This methodology integrates the potential for regeneration, evaluated on the basis of the information contained in the digital version of the Forest Map (Mapa Forestal de España; Ruiz de la Torre, 1990), and the environmental factors that condition this potential. According to the available cartographic information, these environmental factors are: the risk of erosion and the intensity of the dry period.

FACTORS ASSOCIATED WITH VEGETATION

Autosuccession potential

In Mediterranean ecosystems, as a general rule and in terms of potentiality, a process of autosuccession takes place after a fire: the burned plant communities become re-established and, in the short term, reconstitute the same pre-fire communities (Trabaud, 1994, 1998, 2000). This process is also followed in communities dominated by Aleppo (*Pinus halepensis*) and Maritime (*Pinus pinaster*) pines (Ne'eman & Trabaud, 2000; Kazanis & Arianoutsou, 2002; Gallegos *et al*., 2003), although in these cases it is associated with the fire regime or the reproductive capacity of the pine trees (Ne'eman *et al*., 1999; Pausas, 2001).

We assume this autosuccession process in our methodology as general, with the exception of the patches where the sole tree species is pine; to determine the reproductive capacity of pine stands, we consider both the pine species and its age. The Forest Map only contains information on the height intervals of the forest stands, with no indication of age; for this reason we had to use quality curves that relate height and age for each pine species (Gandullo & Sánchez Palomares, 1994).

Three qualitative categories were considered in evaluating the autosuccession potential:

- **Good:** General criterion for all patches with the exception of those with pines as the sole tree species. In the latter case, the patches occupied exclusively by Aleppo or Maritime pines (as the tree species) of more than 3 m in height were considered to have good autosuccession capacity. Within the height intervals used in the Forest Map, the 3 m threshold guarantees the reproductive age of the woodland.
- **Medium:** Patches in which the sole tree species are Aleppo or Maritime pines of between 1.5 and 3 m in height (height interval established by the Forest Map). In contrast with the previous category, at this height interval there is no guarantee that the woodland has achieved fully reproductive maturity.
- **Low:** All remaining cases in which the sole tree species are pines; these generally correspond to tessellations with very young Aleppo or Maritime pines or to patches occupied by *Pinus nigra* A., a species showing very problematic regeneration after fire (Rodrigo *et al*., 1999).

- **Degraded areas:** In the present evaluation of the autosuccession capacity we have not considerd the areas catalogued as degraded (desert or semi-desert in Forest Map terminology). Although their fuel load is very low (and thus the risk of fires, as well) their sparse vegetation cover makes them, in general terms, very vulnerable.
- **Not evaluable:** Patches where the evaluation could not be carried out. These correspond basically to surface areas showing an agricultural-forest mosaic or to areas in process of urbanization for which there is no information on woodland height or composition.

Figure 1 illustrates the spatial distribution of each category. In general, the Valencian forested surface area presents an elevated autosuccession potential, implying that in most of the area a wildfire would not generate any significant variation in the vegetation community in the medium term.

Regeneration rate

The different reproductive strategies (seeding or resprouting) of vegetative species generate significant differences in the response rate (regeneration) immediately after a fire. We evaluated the theoretical regeneration rate of each patch according to the species present; for this, the corresponding reproductive strategy was assigned to each of the four main species (or plant formations) possible. The evaluation of each patch was made on the basis of the percentage of surface area occupied by resprouting species because they show rapid surface cover regeneration shortly after a fire (Ferran *et al*., 1992; Abad *et al*., 1997; Vallejo & Alloza, 1998; Pausas & Vallejo, 1999). The categories established were:

- **High:** Presence of resprouting species on a minimum of 40% of the patch surface. Soil is considered to be effectively protected by vegetation when there is a minimum 30-40% vegetation cover (Thornes, 1995). This requisite, therefore, guarantees rapid protection against erosion with a fast, efficacious response from the vegetation (presence of resprouters and minimum threshold of soil cover, respectively).

- **Medium:** The resprouter cover is less than 40% or undetermined, or there are species with mixed strategy (resprouting/seeding).
- **Low:** Seeder species only.
- **Degraded areas:** Given their intrinsic vulnerability, these areas have been assigned a separate category.
- **Not evaluable:** Patches difficult to evaluate because of lack of information from the Forest Map.

Figure 1 shows the spatial distribution occupied by each category assigned to regeneration rate. The results indicate that in 70% of the Valencian wildland area the response to a forest fire can be expected to be rapid, resulting in quick natural regeneration and soil protection from vegetation.

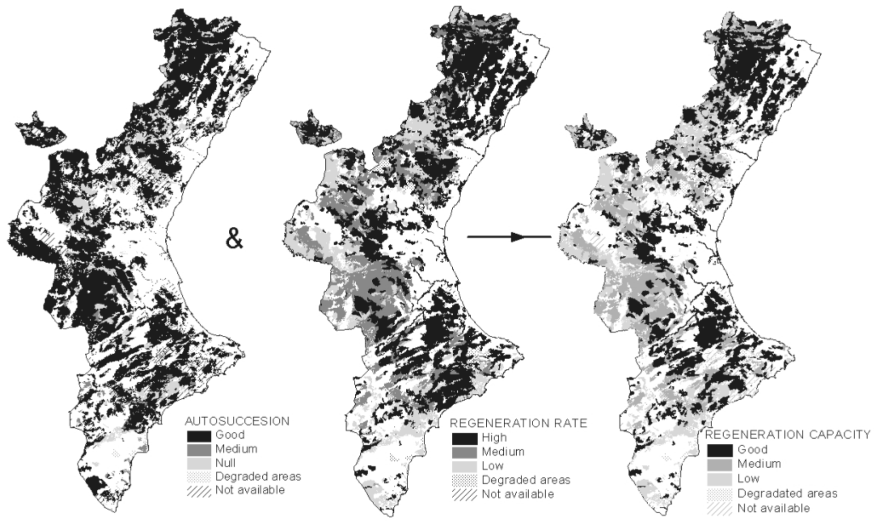

Figure 1. Spatial distribution of the categories of autosuccession potential and regeneration rate, and the integration of both of these to obtain the category of potential regeneration capacity

Potential regeneration capacity

The autosuccession potential and the regeneration rate have been integrated into a single variable which summarizes the potential regeneration capacity. This integration is based on a qualitative evaluation (Table 1), applying a matrix method (MMA, 2000).

Table 1. Integration of the information on autosuccession potential and regeneration rate in order to obtain potential regeneration capacity. Not available: a lack of cartographic information does not allow the assessment

		Regeneration rate			
		High	**Medium**	**Low**	**Degraded areas**
Autosuccesion	**Good**	Good	Medium	Low	Degraded areas
	Medium	Good	Medium	Low	Degraded areas
	Null	Low	Low	Low	Degraded areas
	Degraded areas	Degraded areas	Degraded areas	Degraded areas	Degraded areas
	Not available	Not available	Not available	Not available	Not available

The results obtained (Figure 1) indicate an acceptable regeneration capacity in more than 60% of the surface area, with the regeneration rate acting as the main factor conditioning this potential regeneration capacity.

ENVIRONMENTAL FACTORS

Soil degradation is defined as the decrease in the real or potential capacity of the soil to produce goods and services (quantitative and qualitatively) (FAO, 1979). When this degradation takes place in arid, semi-arid or dry subhumid areas as the result of human activity it is called desertification (UNEP, 1991). The causes of soil degradation are a combination of the inherent fragility of the ecosystems, over-exploitation, and adverse climatic conditions, especially long and recurrent droughts (Pérez Trejo, 1992), with soil erosion constituting one of the main desertification processes in the Mediterranean (Poesen, 1995).

There are currently several methods for evaluating soil degradation and desertification (FAO, 1979; Kosmas, 1999; Sánchez Díaz, 2001). Nevertheless, there are no criteria providing satisfactory and universally accepted results; this can be attributed, among other reasons, to the scant information available (Sánchez Díaz, 2001).

Starting from the complexity of the phenomenon and the cartographic limitations, the present study makes an approximation of the risk of physical degradation on the basis of two variables: the erosion risk and the intensity of the dry period, both of which play an important role in vegetation regeneration processes after a wildfire.

Erosive states

Erosion control has been one of the main objectives of reforestation action plans as well as one of the determining factors in selecting forest action zones, e.g., the National Plan for Priority Actions in Hydrological-Forestry Restoration or the Hydrological-Forestry Restoration and Erosion Control Programme. In these plans and programmes the determination of the erosion risk is based on the Universal Soil Loss Equation (USLE) criteria.

At the Valencia Community scale, a soil erosion map (Antolín *et al*., 1998) based on application of the USLE is available. According to this map, more than 40% of the Valencian forested area would show potential soil losses above 40 t/ha.year (9% would be above 100 t/ha.year); these numbers are very much higher than the 10-13 t/ha.year considered the maximum tolerable threshold for most Mediterranean soils (Poesen, 1995).

The USLE is both the most widely accepted and the most widely used soil-loss prediction model because it aims at maximum facility of application (Castillo & Albaladejo, 1992). Nevertheless, this model does not include all the factors relevant to the phenomenon, run-off volume is not explicitly considered, linear relations are established between all factors, and some forms of erosion are not taken into account (Castillo & Albaladejo, 1992), all of which generate significant overestimations of soil losses (Esteve *et al*., 1990; Sánchez, 1997; Boix-Fayos *et al*., 2003). Significant in this sense is the example of the Xaló river basin, described by Boix-Fayos *et al*. (2003), in which the USLE application indicated high erosion rates whereas the experiments developed in the basin showed maximum values of 0.65 t/ha.h.

To correct for the overestimations resulting from application of the USLE, we made an adjustment on the basis of the bedrock substrate. The potential erosion cover was crossed with the bedrock substrate cover (COPUT, 1998) to reduce to the lowest potential erosion level all the patches situated on limestone or dolomite outcroppings since these rock types develop soils that are both very permeable (Lepart & Debussche, 1992) and only slightly erodible (Cerdá, 1999).

Dry period

As an estimator of dry period intensity, we calculated the Dry Bioclimatic Intensity (IBS) according to the methodology of Montero de Burgos & González Rebollar (1983). The IBS is an indicator of a month's dryness expressed in bioclimatic units (one bioclimatic unit represents 5°C a month); it is obtained by using the following formula:

$$IBS = - [(e - D) / (E - e)] * [(T - 7.5)/5]$$

Where:

e: Evaporation residual or through immobilized sap flow; this is estimated to be 20% of the Evapotranspiration
D: Water availability (mm)
E: Evapotranspiration (mm)
T: Average temperature (°C)

For the IBS calculations we used the average annual values from 110 thermopluviometric stations (data taken from Pérez Cueva, 1994) and the methodology of Montero de Burgos & González Rebollar (1983), with the following considerations:

- To calculate balances we estimated a reserve of 50 mm for all forested areas, to correspond with the limited depth of Valencian forest soils.
- To estimate run-off losses we considered the topography of each forested patch. For this, we overlaid the landscape unit cover (taken from Antolín, 1998), assuming a run-off percentage of 10% in patches situated on slopes of less than 8%, and a run-off percentage of 30% in all other patches.
- To find the water balance for the 110 thermopluviometeric stations, we calculated the potential evapotranspiration according to the Thornthwaite model.
- The IBS results were extrapolated to the territory by applying a kriging.

Degradation risk

Erosion risk and dry period intensity were integrated, using a qualitative assessment, into a variable denominated *Degradation risk due to physical factors.* The categories considered are indicated in Table 2.

Table 2. Integration to obtain the degradation risk in terms of erosion potential and dry bioclimatic intensity.

		Dry bioclimatic intensity		
		High	**Medium**	**Low**
Erosion potential	**Low**	High	Medium	Low
	Medium	High	Medium	Medium
	High	Very high	High	Medium

The results obtained indicate that 37% of the total Valencian wildland area shows a high or very high risk of degradation (Figure 2); this is generated from the combination of high erosion risk and important drought-imposed limitations. Nevertheless, it should be pointed out that, after applying the erosion-rate reductions due to bedrock substrate, the highest erosion rates are reduced from 84% to 42% of the wildland areas, which are more in line with the values observed in field experiments.

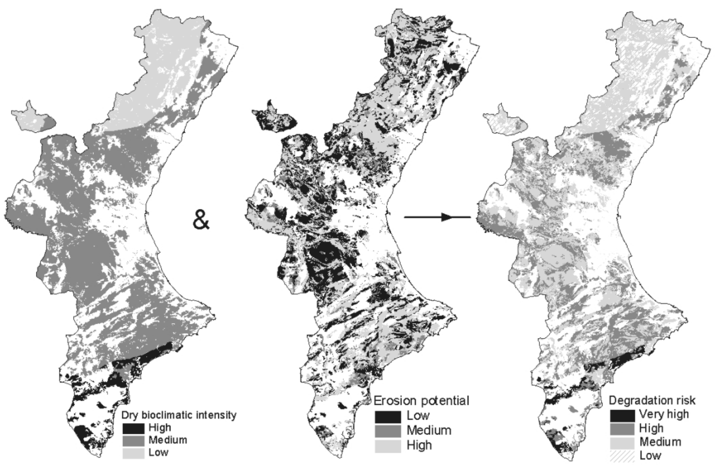

Figure 2. Distribution of dry period intensity, erosion risk (modified according to bedrock substrate) and degradation risk

Vegetation fragility in relation to forest fires

In environmental studies, fragility (or vulnerability) refers to the degree of susceptibility to deterioration in relation to certain actions; it can also be defined as the inverse of the capacity to absorb possible changes without losing quality (MMA, 2000).

Using the methodology described, the areas most vulnerable (fragile) to forest fires are those where a low regeneration capacity coincides with a high degradation risk. These areas are identified by overlaying the intrinsic factors of the vegetation on the environmental factors analyzed. The integration of both factors was done by means of a qualitative assessment, as can be seen in Table 3.

The results indicate that 14% of the total Valencian wildland area presents very high fragility in relation to forest fires (Figure 3). This means that, in the event of a forest fire in these areas, some degradation of the vegetation cover can be expected to be produced in the short term.

Table 3. Integration of regeneration capacity and erosion risk, in order to evaluate vegetation vulnerability to forest fires

		Regeneration capacity				
		Low	**Medium**	**High**	**Degraded areas**	**Not available**
Degradation risk	**Very high**	Very high	Very high	High	Very high	Not available
	High	Very high	High	Medium	Very high	Not available
	Medium	High	Medium	Low	High	Not available
	Low	Medium	Low	Low	Medium	Not available

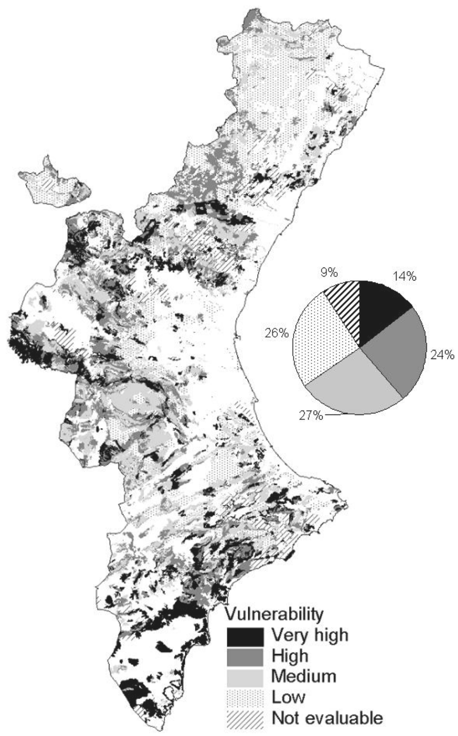

Figure 3. Spatial distribution and percentages occupied by each of the fragility categories

APPLICATIONS FOR PRIORITIZING ACTIONS

In the Spanish Forestry Plan, the category “surfaces susceptible to restoration” refers to areas that are subject to erosion processes and that present a vegetation cover with scant protective capacity (MMA, 2002).

Application of these criteria reveals that there are 590,957 ha (40 % of wildland surface area) in need of restoration actions in the Valencia Regions. Such an extensive area necessarily calls for prioritizing criteria, and for this, the evaluation of fragility can be applied as an indicator of the susceptibility to deterioration (Table 4).

Table 4. Assignation of reforestation priorities, based on the degree of vegetation fragility, for zones of shrublands and agricultural-forest mosaic with a low maturity level

		No signs of improvement in tree cover	Signs of improvement in tree cover
FRAGILITY	**Very high**	High	Medium
	High	High	Medium
	Medium	Medium	Low
	Low	Medium	Low
	Not available	Not available	Not available

This methodology cannot be used to evaluate areas that, in spite of registering an elevated degradation risk, present a high maturity level In these cases, rather than vegetation cover restoration, actions are needed to conserve and/or improve the vegetation cover by means of silvicultural actions (MMA, 2002).

PROSPECTS

The methodology described represents a flexible tool that permits the incorporation of the latest advances in ecosystem response to fires with the use of available cartographic information. It also represents an example of the application of scientific research to Forestry Management, and it has been incorporated into the Valencia Region General Plan of Forest Management (PGOFCV, 2002).

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IMPACT OF FOREST FIRES ON HYDROLOGICAL PROPERTIES OF A TYPICAL MEDITERRANEAN FOREST SOIL

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ABSTRACT

Fire is one of the most important determining factors in the evolution of Mediterranean ecosystems. Its effects on soil are plural and diverse, acting on structure, chemical and physical properties, biota etc. Among them, the induced variations on soil water dynamics are of key importance for the recovery of the entire ecosystem and in the soil response to erosion processes. Forest fires are also a factor, triggering the risk of desertification. The aim of this study is to assess the impact effect of different fire intensities on soil hydrology and on runoff generation.

This work was developed in the Permanent Experimental Field Station of La Concordia with nine plots (4 x 20 m), installed in a calcareous hillside, representative of Mediterranean shrubland areas. Experimental fires, of two intensity levels were carried out. Three plots were burned reaching high fire intensity and three other plots were burned with moderate intensity and the remaining plots were left undisturbed as control. Soil water content, water retention capacity and pF curves were measured together with runoff generation dynamics, in the different plots. The intrinsic characteristics of each rain event occurred up until a year after the fires and runoff generated on them was monitored.

The data obtained was compared with the state of the plots after seven years, during the 2000-2002 period. In this period 24 rain events with runoff generation occurred, with average rainfall intensities (I_{30}) around 10mm h^{-1}. Both fire treatments show significant differences with respect to the Control plots, which are reflected in a value of runoff production of 76.84% as an average, less than the burned plots. Between fire treatments, the plots that burned with high intensity, show the highest values of runoff yield. However, infiltration rates do not give significant differences between fire treatments.

In the same way, plots that suffer a high intensity fire show greater values (22.50 cm^3 cm^{-3}) on water retention capacity than the other treatments, giving significant differences with the Moderate intensity plots and Control plots. Differences on this parameter between plots burned with Moderate intensity and the Control plots were observed but they were not

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statistically significant. The obtained pF curves show the same tendencies, being the greatest water content retained at pF of 2 in the burned plots and in the Control plots at pF of 4.2.

The effect of fire degrading the vegetation cover and by means of the temperature impact on soil, produce changes in its structural characteristics and porosity, affecting soil water distribution and the effective response on water erosion processes.

Keywords: water retention capacity, pF curve, hydrology, experimental fire, Mediterranean, desertification.

INTRODUCTION

Wildfires are known to have occurred in the Mediterranean region through historic and prehistoric times (Naveh, 1990). In the last few decades, fires of human origin have substantially increased not only in their number but also in their frequency, which have produced reduction in the recovery periods and could drastically change or even eliminate the vegetation cover, changing and degrading the ecosystem characteristics (Andreu, 2002).

Actually, different studies indicate that the tendencies of fires in the Mediterranean region are to decrease the affected area but increase in number (European Commission, 2002). It could mean that many regeneration zones could be affected by fire again, breaking its possibilities of resilience and becoming in regression by alteration of its physical, chemical and biological functions and processes. Forest fires also increase desertification risk in the Mediterranean, particularly when there are some critical circumstances, such as: fire on very step slopes and shallow soils underlying consolidated parent material; fire affecting vulnerable soils or soil with poor conditions for its re-vegetation; the effects of repeated fires on the same area and also the incidence of torrential rain in recently burned areas.

In the Mediterranean area, as a result of the high rainfall intensities concentrated after the dry summer period, where the fires occur, soil infiltration and even water storage capacity, mainly in shallow soils, is easily exceeded, generating important soil losses and high energy runoffs as a consequence of the relief features (Rubio and Calvo, 1996) that can reach as much as one to three orders of magnitude (De Bano, 2000; Robichaud, *et al.*, 2000). This is usually due to soil changes induced by fire, which depending on its severity or intensity, could be beneficial or deleterious to the ecosystem (Neary, *et al.,* 1999). Between these changes, loss of vegetation cover and soil structure alterations are factors that produce amplified hydrological responses (De Bano, 1998).

Generally, the high intensity fires and the greater structural breakdown of aggregates, produce formation of microaggregates and liberation of soil particles, easily removed by runoff (Prosser and Williams, 1998; Benavides-Solorio and McDonald, 2001). This effect will favour soil sealing, crust formation, decreasing soil water retention capacity and reduction in pore size characteristics that incise directly in a reduction on infiltration and drainage increasing soil erodibility (Le Bissonais, 1996; Terman and Neller, 1999; Andreu, *et al.*, 2001).

Post-fire conditions of the surface horizons are of key importance because they determine the response of soil exposed to raindrop splash, overland flow and the development of water repellent soil conditions (De Bano, 1981). These changes in soil characteristics and the degradation of the vegetation cover and litter layers can lead to very large increases in soil erosion (Benavides-Solorio and McDonald, 2001).

These facts suggest that one important way to carefully study the effects of fire on the soil ecosystem is through the performance of fires in experimental plots (Giovannini and Luchesi, 1997). Then it is possible to know and measure soil conditions before, during and after the fire experiment and to improve the knowledge about the hydrology of the zone affected by fire which could reach different intensities.

In this context, the aim of this study is to evaluate the evolution of the hydrological characteristics of a typical Mediterranean forest soil affected by different fire intensities in 1995 and compare it with its state in 2002. Changes in the response of these soils on runoff generation in each erosive rain event of the time period considered have been also studied.

MATERIALS AND METHODS

Study Area

This work was developed in the Permanent Experimental Field Station of La Concordia (Lliria, SPAIN), at 50 km NW of Valencia city. It is 575 m above sea level (Figure 1), on a forested hillside facing South South East, with a sclerophyllous shrub cover, regenerated after a previous wildfire occurred in 1978. The most abundant species include *Rosmarinus officinalis*, *Ulex parviflorus*, *Quercus coccifera*, *Rhamnus lycioides*, *Stipa tenacissima*, *Globularia alypum*, *Cistus clusii* and *Thymus vulgaris*.

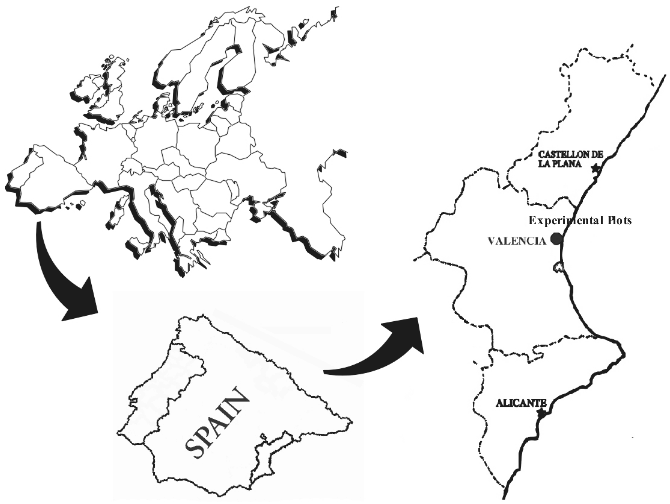

Figure 1. Geographical location of the Permanent Experimental Field Station of La Concordia (Casinos, Spain)

Climatically the area belongs to the dry ombroclimate of the lower mesomediterranean belt, according to Thornthwaite's classification. The average annual precipitation is around 400 mm, with two maxima, autumn and spring, and a dry period from June to September with mean monthly temperatures ranging from 13.3ºC in January to 25.8ºC in August.

The soil is a Rendzic Leptosol (FAO-UNESCO, 1988), or Calcic Xerochrept type according to Soil Taxonomy classification (Soil Survey Staff, 1990), developed on Jurassic limestone. This soil has a variable depth, always less than 40 cm, abundant stoniness (≅ 40%) and good drainage.

Experimental Set-Up

The station consists of a set of nine erosion plots, each 4 m wide x 20 m long, with similar characteristics such as soil morphology, slope gradient, rock outcrops and vegetation cover. The selection of each plot location was made after intensive surveys of the vegetation, soil and the morphology pattern, based on across slope transects every two meters.

Plots are oriented parallel to the slope and bounded by bricks. At the foot of each plot, a 2 m wide collector ran into a 1500 l tank to record all the runoff and sediment produced during each rainfall event. Inside them there is a 30 l tank to concentrate the sediments produced, facilitating its collection.

A random design of three different fire intensity treatments (with three plots each) was used. Two sets of three plots were burned reaching High and Moderate fire intensities, which was achieved by addition of different amounts of fuel load to the plots of each treatment, 40 and 20 t ha^{-1}, respectively. The remaining three plots were unburnt to be used as a Control treatment. The necessary quantity of dry biomass to obtain the two fire intensities was added using vegetation (from the surrounding area) similar to that present in the plots.

Climatic parameters and the intrinsic characteristics of the different rainfall events were monitored by a logging system of sensors with GSM transmission of data, placed close to the plots.

Soil Analysis and Measurements

Soil samples were taken from the top 5 cm of the soil surface before and immediately after fire, and in the summer of 2002, they were air-dried, screened to remove the fraction >2 mm diameter and stored in plastic boxes until their analysis.

Soil Water Content (SWC) was calculated for the potentials: 0, -10, -33, -300, and -1500 KPa, or pF 1, 2, 2.5, 3.5, 4.2, using the pressure membrane method (Richards, 1947). Soil Water Retention Capacity (WRC) was calculated for each soil sample using the equations of McLaren and Cameron (1996).

$$\textbf{(a) } \mathbf{WRC=(\,\theta_{10} - \theta_{1500}\,)^{*}\,\rho_b} \qquad \textbf{(b) } \mathbf{WRC=(\,\theta_{33} - \theta_{1500}\,)^{*}\,\rho_b}$$

Where WRC is soil Water Retention Capacity, θ_{10}, θ_{33}, θ_{1500} are gravimetric water volume at -10 KPa, -33 KPa, and -1500 KPa, and ρ_b bulk density of soil samples. The results were obtained in volumetric units in percentage.

Water Retention Capacity with field capacity at -10 KPa (a) and with field capacity at -33 KPa (b), were calculated for the different plots. The pF curves were also determined.

Runoff generation dynamics were monitored for each rain event in all plots, during one year after the 1995 fires and in the period of 2000-2002.

Soil organic matter content was determined by oxidation with potassium dichromate (Jackson, 1958). Total Nitrogen was determined by micro-Kjeldahl automatic analyser using the Bremmer method (Black, 1965). Ammonium and nitrate Nitrogen were extracted with 2N KCl solution and determined by steam distillation by micro-Kjeldahl automatic analyzer using the Bremmer method (Black, 1965). Electrical conductivity was measured in soil saturation extracts by the Richards method (1964). Available Phosphorous was measured by colorimetry according to the Olsen and Dean method (Black, 1965). Aggregate stability was assessed using a wet-sieving procedure (Primo and Carrasco, 1973).

Standard statistical analyses were applied at 95% of signification level. Analysis of variance and Tukey's test at α=0.05 were used to detect differences in WRC and pF values, according the different fire treatments.

MAIN RESULTS AND DISCUSSION

Rainfall trends

During the studied period (2000-2002), 24 rain events with runoff generation were monitored, showing average rainfall intensity (I_{30}) of 9.38 mm h^{-1}. The rain behaviour in year 2002, on quantity, characteristics and distribution, showed a change compared to the previous years (Figure 2). Since the Experimental Station started in 1995, the trend of the precipitations in the area has showed substantial variations, among those it is necessary to highlight the intense period of drought which occurred during 1998 and 1999. Year 2000 observed a certain tendency of recovery in the rain regime, reaching 415.90 mm of the annual rainfall. However, although the total annual rainfall in year 2002 reached 521.50 mm, a net decrease of precipitation occurred in 2001 with a total rainfall of only 267.40 mm.

It is also possible to appreciate this variability in the characteristics and monthly distribution of the rain events. The distribution of rain in 1995 and 2001 could be considered as typical of the Mediterranean region climatology, with precipitation concentrated mainly in September-November and March-May, and long dry periods at other times (Perez Cueva, 1994). The number of erosive rain events increased in the studied period, from 38 episodes in 2000 up to 49 in 2002. In general, it is in the months following the dry season where the larger intensity rains are concentrated. This tendency strongly changed during 2000 (Figure 2) in which after the dry season, 64.10% of the total annual rainfall was collected in October only (266.60 mm). In this month, 132.8 mm corresponds to one single event occurred on day 23rd.

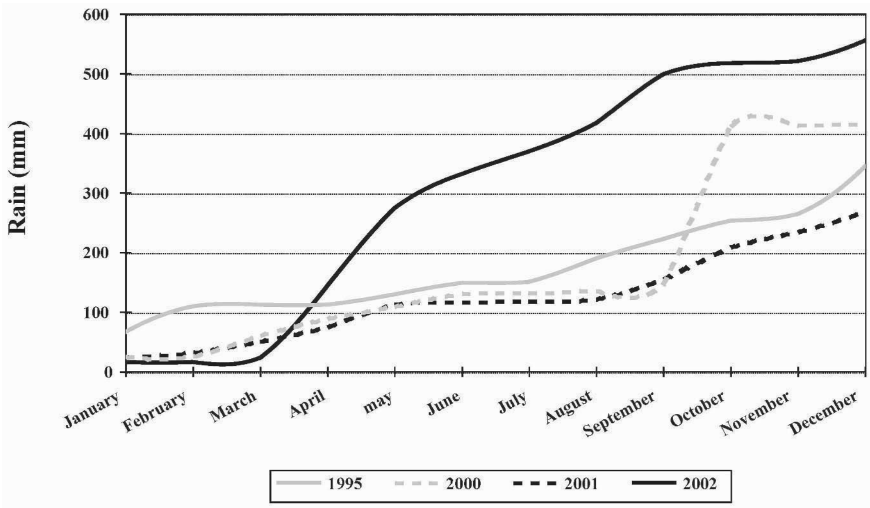

Figure 2. Cumulative monthly distribution of rain during 1995 and 2000-2002

2002 also marked a change in the distribution, volume and duration of rains compared to previous years. In this year the highest values of precipitation occurred from April until September, during the summer period, which is usually affected by water deficit, 224.4 mm were collected.

During the years 2001 and 2002, an increase in the number of erosive events compared to previous years was observed, with 8 erosive rain events of 45 rain episodes and 10 of 49, respectively. In 2000, only 6 erosive rains out of 38 events were registered. It is similar to those which occurred in 1995, but with greater volume and duration of the erosive rains. The characteristics of the erosive rain events which occurred during the studied period can be observed in Figure 3.

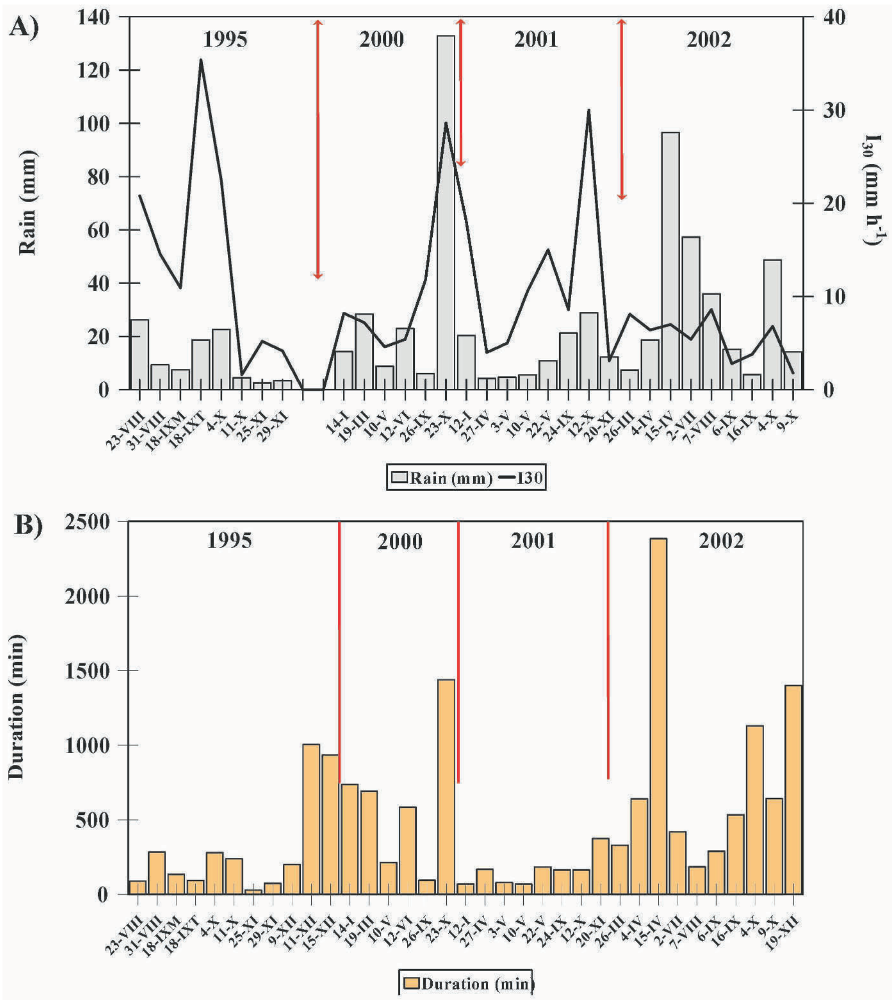

Figure 3. Erosive rain events occurred in 1995 (after the fire) and in the period 2000-2002 (A), and duration of these rain events (in minutes) (B)

During 2002 the erosive rains suffered a clear decrease in their intensity, with a maximum value of 8.6 mm h^{-1} whereas on 1995, 2000 and 2001 were of 35.36 mm h^{-1}, 28.6 mm h^{-1} and 30 mm h^{-1}, respectively. These peaks of intensity were usually accompanied by some reduced volume events, not surpassing 29 mm. But during 2002, four erosive events surpassed 35 mm, one of them reaching 96.5 mm of the total rains (15-IV), with an average intensity that did not exceed 5.63 mm h^{-1} (Figure 3). These facts were accompanied in 2002 by an increase in the duration of rains, whose minimum values (185 min) have duplicated those for 1995, 2000 and 2001. In this way, 2002 showed an increase in the number of rains and in their duration but with a clear diminution of intensities. These facts favoured a decrease in the number of erosive rains and the maintenance of the soil humidity conditions along the year.

Runoff processes

In Table 1 are reported some soil characteristics analyzed in samples taken in 2002.

Table 1. Mean values of some soil properties on each fire treatment in 2002

Soil Property	Fire Treatment		
	High	Moderate	Control
pH	7.88	7.88	7.84
E.C. (dS m^{-1})	0.64	0.65	0.68
A.S. (%)	32.96	33.47	32.03
O.M. (%)	7.92	7.88	7.15
Total-N (%)	0.364	0.356	0.361
NH_4^+ -N (mg $100g^{-1}$)	0.776	0.844	0.888
NO_3^- -N (mg 100 g^{-1})	0.875	0.787	0.536
C.E.C. ($cmol_ckg^{-1}$)	27.453	26.171	26.45
Na^+ (%)	0.400	0.386	0.322
K^+ (%)	3.182	3.050	3.424
Mg^{2+}(%)	3.962	3.436	3.760
Ca^{2+}(%)	92.585	93.135	92.485

E.C: electrical conductivity; A.S.: Aggregate stability; O.M.: organic matter; Total-N: total Nitrogen; NH_4^+-N: ammonium Nitrogen; NO_3^-- N: nitrate Nitrogen; C.E.C.: cation exchange capacity. Na, K, Mg and Ca: exchangeable cations as percentage of the C.E.C.

As it has been observed, the characteristics of rains during 2002, could have favoured the upholding of a certain degree of soil humidity throughout the year, without a real period of summer water deficit. This situation could facilitate runoff generation but in turn, maintaining the soil in a state of better muffling of the impact of rain drops. This situation, with moderate/low rain intensities, did not favour the generation of aggressive runoffs and the removal of soil particles. So, for the control soil and burned ones, the previous highest water content and the low rainfall intensities during the different seasons, could have improved the infiltration rates and diminished runoff yields and water repellency (Benavides-Solorio and Mc Donald, 2001). Robichaud (2000), observed that the hydrophobic conditions that appeared in the soil surface after fire impact, vary as the soil profile becomes wetted and eventually responding as a normal infiltrating soil. De Bano (1981), note that infiltration increases with time because the hydrophobic substances responsible for the water repellence are slightly water soluble and dissolve slowly, thereby increasing soil wettability. This fact was confirmed by observations in the field and by the data of runoff generation during the year 2002 (Figure 4).

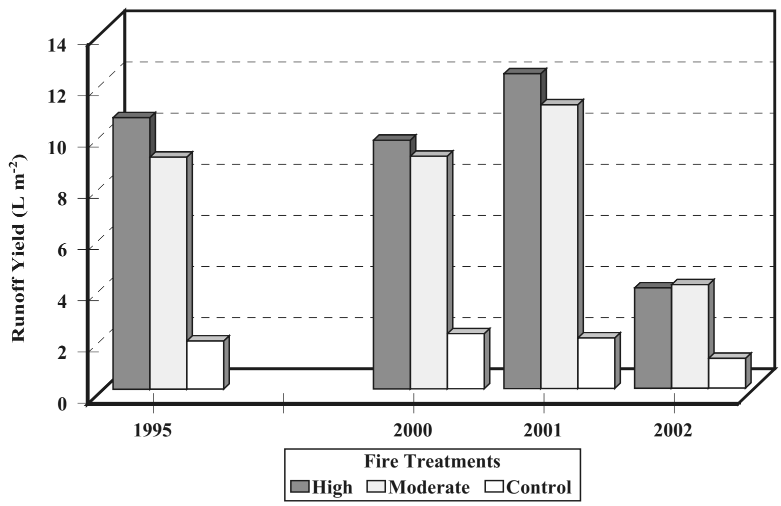

Figure 4. Total values of runoff yield (L m^{-2}) corresponding to different treatments during 1995 (after fire) and the 2000-2002 period

This great variability in the distribution and characteristics of rains observed during the period of 2000-2002, has been clearly reflected in the general hydrological behaviour and also in the response of the plots corresponding to the two fire treatments in relation to the incidence of the water erosion processes. These plots showed significant differences in respect to the Control plots on their hydrological values during this period. This fact is reflected in an average value of runoff production in the Control plots of 76.68 % less than the burned ones (Figure 4) for the whole period. However, these differences slightly diminished in 2002 due to the change in rain characteristics, with a clear reduction in their intensity and an increase in their duration, but continue being significant (Figure 3 and 4). Differences observed on the fire treatments in respect to the Control plots are similar to that observed in 1995 after the fire (84.10%). Only in 2002, these differences diminished around 14 % respect to 1995.

Between fire treatments, the differences on runoff production have clearly decreased from 14.60% more runoff for plots affected by High intensity fire in 1995 to 2.73 % in 2000. Actually, the plots burned with Moderate intensity present the highest rates of runoff yield. This reflects an equilibrium of soil conditions and the regeneration of the vegetation cover.

Infiltration rates do not give significant differences between treatments during the studied period (Figure 5A), which are usually lower than 1%. Plots not affected by fire always give the maximum values. In 1995 the differences observed between fire treatments do not reach 1%, but in regard to the Control plots, these differences were an average of 5.39%. In the year 2002, the differences between burned plots and Control plots were reduced to 1.18 %. It was partly due to the softer rainfall regime during this year and to an improvement in the vegetation and soil characteristics.

The data of runoff coefficient (Figure 5B) show a slight decrease in the differences between the control plots and those affected by fire. As an average, in 1995 control plots give 79.62% lower runoff coefficients than the burned plots, but from 2000 until 2002 this difference was gradually reduced to 73.18 %. Between fire treatments, there were important changes. In 1995, plots burned with Moderate intensity presented 12.02 % less runoff coefficient, meanwhile in 2002 the tendency changed, plots burned with Moderate intensity presented the highest values of it.

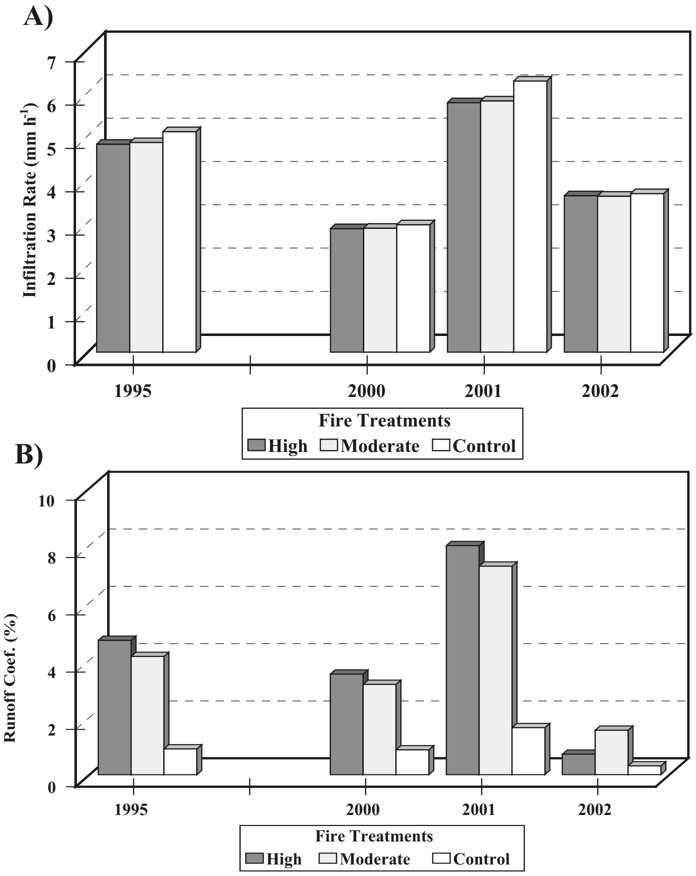

Figure 5. Average values of infiltration rate (A) and runoff coefficient (B) correspondents to the different treatments during 1995 (after fire) and 2000-2002 period

The trend observed on both parameters could indicate a slight amelioration of the hydrological conditions of these soils in respect to those immediately after the fire impact. Doerr, *et al.* (1996), found that the hydrophobic character of burned and unburned soils, when dry, tend to disappear as the soil becomes wetter in low intensity events. However, changes in the rain regime can produce a response similar to that stated in 1995, a clear example is shown by the data corresponding to 2001. The strong reduction of rainfall volume occurred in that year, with a decrease in the duration and with an increase in the intensity of rains, which was accompanied by a concentration of the most aggressive events after a long dry period (April to September), producing a faster and greater runoff generation, probably due to the incidence of water repellency in the soil and less receptive soil hydrological conditions. In addition to that, the degradation of vegetation cover and the changes in soil characteristics because of fire, could produce an increase in the hydrological response, especially in the High fire intensity treatment. These effects are in accordance to the observations of different authors in similar shrubland environments (De Bano, *et al.*, 1998; Johansen, *et al.*, 2001).

Hydrological evolution

Data obtained on soil Water Retention Capacity (WRC), on samples of 1995 and 2002 (Table 2), for a matric potential of -10 KPa (pF 2), show significant differences between High fire intensity plots and those corresponding to the Control treatment immediately after the fire experiment (1995). This data is in agreement with the observations of Malik (1984) on the WRC on superficial soils samples. Just immediately after fire, WRC is greater on burned areas than on natural soil. This could be explained by considering that the ash particles in the burned plot clog the soil pores in the upper soil layer, thus the density of the larger pores is reduced and as a consequence, this reduces the rate of water percolation throughout the soil and increases WRC. This parameter shows its greatest values in the High intensity treatment, 26.6 % being higher than those of the Moderate intensity treatment, and 31.11 % greater than the control one (Table 2).

Seven years later, in 2002, control plots present higher values of WRC than burned ones. Boix-Fayos (1997), found a similar tendency in a Mediterranean soil that suffered the impact of fire three years before, in respect to unburned soil.

The fact that soil affected by High intensity fire, presents greatest values of WRC than unburned soil immediately after burning, could indicate that changes in physical properties in soil surface appeared (Andreu, 2001). These changes could be produced in particle-size distribution and aggregation, by the re-aggregation of clay size particles into sand-size ones (Giovannini, 1994). This effect could favour higher water holding at low pF values (Table 2). So, there is an important quantity of water retained in soil at low pF values, probably stored in the gaps generated by the re-aggregation of clay particles into sand size ones. When the WRC is calculated on a basis of a matric potential of -33 KPa, the possible effect of the water held by the sand-sized particles is eliminated, and the differences between fire treatments disappear (Table 2B). The fire effect could favour high water holding at low pF values. Between the values -10 KPa and -33 KPa, the held water content is 75% and 55% higher for High and Moderate intensity treatment in respect to the Control values (Table 2). Then, there is an important amount of water held in soil at low pF values for the High intensity treatment. Guber *et al*. (2003) classifying aggregates by size using the average water content at -10 KPa, -33 KPa and -1500 KPa, found that larger aggregates present the greatest variation on water content and the greatest values on this parameter.

Table 2. Values of water retention capacity (WRC, cm^3 cm^{-3}) calculated at matric potentials of -10 KPa and -1500 KPa, and -33KPa and -1500KPa, for the different fire treatments immediately after the fire experiment (1995) and in 2002 period

		TREATMENTS		
		High	**Moderate**	**Control**
WRC 10 KPa	**1995**	**0.225 a**	**0.165 b**	**0.155 b**
	2002	**0.182 ab**	**0.178 a**	**0.202 b**
WRC 33 Kpa	**1995**	**0.105 a**	**0.135 a**	**0.100 a**
	2002	**0.131 a**	**0.136 a**	**0.170 b**

Values not sharing the same letter in files indicate significant differences for the different treatment according to the Tukey´s test ($P<0.05$).

Figure 6 shows the pF curves of soil water content for 1995 and 2002. Data corresponding to 1995 shows that immediately after fire, the water content at low pF (2) presents it's greatest values on plots affected by High intensity fire. However, at high values of pF (3.5 and 4.2), the tendency changes, Control plots show greater levels of water content than the burned ones. These increasing values of water content depend partly on structural changes in the topsoil after fire. It could be due to an increase in macroaggregates fractions, favored by cementation particle processes (Andreu, 2001) produced, mainly because of the temperature effects on calcium carbonates, iron and aluminum oxides (Giovannini and Luchesi, 1997; Terman and Neller, 1999).

The possibility of increased macroaggregates in soil surface layers, could explain the volume of water retained in the soil affected by fire at low pF values. At these levels, the amount of water depends primarily upon the capillary effect and the pore-size distribution and hence is strongly affected by soil structure (Hillel, 1980). If the percentage of macroaggregates rises, the volume of water held between transformed particles could increase, allowing that the values of water content on burned soils were higher than in the Control.

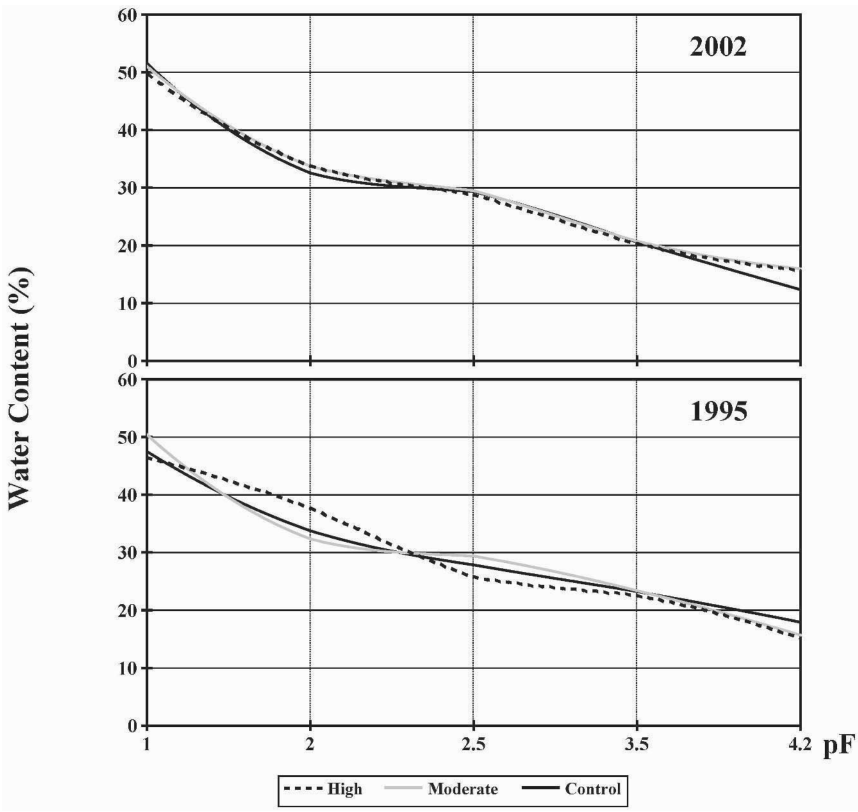

Figure 6. Water content for the different treatments in 1995 (after the fire), and 2002

There are important differences between soil burned and soil not burned at high suction pressures, with the water content higher on Control plots than in burned ones. It is important to remark that water retained at higher suction levels (pF 3.5 and 4.2) is mainly due to adsorption processes and thus, is influenced more by the texture and the specific surface of soil materials than by structure characteristics (Hillel, 1980; Ingelmo, 1986).

The fact that water content is higher on Control plots can be evidence that a percentage of the clay fraction (principal particles involved on water retention at high suction values) could be transformed into sand fraction by the fire impact. Bruand, *et al.* (1996), finds a negative relation between bulk density and water retention at pF 4.2. Soil samples with low values of bulk density and with a high percentage of clay mineral, show major values of water content at pF 4.2 than soil samples with less content of clay minerals.

In 2002, significant differences between burned and control plots were only observed at pF 4.2 (Figure 7), at these high values of matrix suction, the burned plots show higher levels of retained water than Control ones.

The levels of water retained in 2002 present greater values than those of 1995 at low pF values (Figure 7). On control samples and for pF 4.2, there is a significant variation on water content from 1995 to 2002. Water contention values at pF 4.2 on samples taken in 1995, are higher than the water content for the same pF in 2002, while at low pF values in 2002, there is an increase in the water content. The vegetation recovery during these seven years facilitate that in superficial layers it must be an improvement for the water holding at low pF values and hence a better soil structure.

The general trends observed, as it has been reflected by the data, show an amelioration of the general hydrological conditions seven years after the fire. However, after this time, runoff production and coefficients in the burned plots are still far from the behavior observed for the unaltered ecosystem. Several authors indicated that usually soil erosion rates return to pre-disturbance levels within 3 to 9 years after burning (Robichaud, *et al.,* 2000; Benavides-Solorio and Mc Donald, 2001), but it could be not enough resilience time in the Mediterranean conditions with a very variable rain regime and recurrent drought periods.

CONCLUSIONS

The evolution of soil and vegetation during the seven years after the fire, have produced important changes on hydrological properties. It is reflected, mainly by the net reduction of differences on hydrological characteristics between fire treatments, although these differences continue being appreciable in relation to the plots not affected by fire.

Changes in rain regime have led to significant differences on runoff generation between treatments and years. In this sense, the marked decrease on intensity, and the increases in number, volume and duration of the precipitations occurred in 2001, produced similar consequences than those observed in 1995. These circumstances resulted in bigger differences between burned plots and Control ones in runoff production.

Water Retention Capacity in 2002 in plots affected by fire, has become similar but is still lower than the values observed in the control plots. This is a difference of nearly 60% with respect to levels of 1995.

Analysis of pF curves shows an amelioration of soil hydrological conditions regarding 1995, with an increase of water content in all treatments, showing a similar behavior among them. Only slight differences were observed at the extreme pF values (1, 2 and 4.2).

The recoveries of soil and vegetation characteristics, during a period of seven years, have been of great importance with regards to the hydrological characteristics of the soils affected by fire. However, this period has not been enough to reach its total recovery, as is clearly shown by the differences with the unburned plots. In Mediterranean ecosystems, where the maintenance of the fragile soil hydrological conditions allows the subsistence of ecosystems and human communities, the incidence of fires is magnified by changing climate conditions and the rainfall regime of the zone. This fact is made more critical by the tendency towards the increase in frequency of forest fires, which could favour progressive ecosystem degradation and the increase of desertification risk not only as an environmental problem but also with socio-economic consequences.

ACKNOWLEDGEMENTS

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MANAGEMENT OF FOREST SOILS CONSIDERING WATER EROSION AS A CONTROL FACTOR

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ABSTRACT

In Mediterranean regions, water erosion is strongly linked to desertification and relates mainly to constraints of land use. Soil and water play very important roles as production factors in agriculture and forest crops, so they are of almost importance in the management of forest soils for sustainable productivity.

The density of plants, the amount of water available and the soil properties are aspects to take in account in the management of forestlands. The lower stage canopies of bushes and herbs established in forest lands compete for water with the trees, but are important in the maintenance of ecosystems and absorbing the energy of rainfall and throughfall, thus reducing soil erosion.

For the assessment of the available water and the rainfall erosion it is necessary to know the hydrologic behaviour of tree canopies and, mainly, the role of the leaves. The major aim of this study is to present and analyse the role of the leaves in what concerns canopy interception, retention and throughfall and to present values for the leaves' retention and throughfall erosivity, obtained experimentally.

Typical conditions, in Southern Portugal, are presented for mixed stands of cork and evergreen oaks, with cereals or pasture covers, and for eucalyptus.

Proper management attitudes are necessary to ensure productivity, environment stability (i.e. avoiding desertification) and, consequently, improve homeland and global security.

***Desertification in the Mediterranean Region*: *a Security Issue,* 509–523.**
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INTRODUCTION

The adequate management of forest soils is necessary to ensure a proper relation between land quality, forest productivity, environment sustainability and global security.

Actually, one of the major questions presented to land managers is to encompass the right appropriation of land attributes, the land use and the productivity of the exploitation of natural resources, keeping balance with the socio-economic and environmental sectors and assuring a policy of access of the population to the welfare, provided by natural resources and other goods, in the framework of homeland and global security.

Forests and tree plantations in general, as major providers of resources and goods of first necessity such wood and other general food commodities, must be managed appropriately in order to made those goods available and supplied to the markets, for the use and benefit of People.

To provide the most benefit from the forest and tree resources, with the minimum environmental and socio-economic costs, in their exploitation and management, it is necessary to improve the technological tools and processes used.

Besides other aspects of the management of the land and of the production factors, the soil, the water and other climatic variables are major attributes that must be taken into account in the right exploitation of forest and other tree plantations.

Since long time ago, agriculture, namely irrigated agriculture, developed a comprehensive set of technological tools and processes to obtain the most profit from the soil and the cultivated vegetation. A similar methodology was not yet commonly adopted as an ordinary procedure, like a code of good practices, in the management of forestlands, at least, in most of the Mediterranean countries an in developing countries.

The right use of practices and technological tools in the management of forestlands is of great importance in particular environments very sensitive to their soils and climatic characteristics. This is the case of forests in Mediterranean and semiarid climates where water shortage can occur in long periods, submitting the forests, in particular newly established stands, to stresses due to water deficits.

It is also quite common, in developed countries and in other regions where land is highly valuable, that forests are left to soils with marginal value to agricultural use. Thus, this situation even creates a more critical problem in what concerns the management of soil, water and vegetation and presses for the use of highly accurate and advanced technological tools and procedures.

WATER AND SOIL CONTROLS

Unlikely to the development of forests in natural conditions, where all the soil, water and climatic variables involved act together towards the equilibrium to attain the "climax" vegetation conditions, the forestlands established by Man must be managed to obtain an optimum equilibrium.

It is well known that soil, water and climatic variables are the most important natural factors in the management of forests and that the behaviour of the soil, water and vegetation interactions plays a major role in that management. Also, other constraints in the availability of those basic resources, induced by man, as well as the demands of the consumption markets, set the general framework in which the management conditions must operate.

In a managed system it is necessary to have a very good knowledge of the major control parameters, the prime objectives concerned and of the costs, risks and uncertainties related to the established management methodologies and operations.

The major objective of this article is to describe and emphasise the hydrological controls, in general, and the water effects in the soil erosion, in particular.

The hydrologic control and the interaction of soil, water and plants act at three time wise situations - *continuously*, in time; in *short periods,* occurring seasonally or of medium duration; and, in *episodes or events* of short or very short duration.

For the *continuously* situation, the average nature and values of the variables are responsible for the principal characteristics of the forests, their dominant species, stand densities, the management procedures, the calendars of the forest operations and the average values of the outputs. The outputs from the forest cannot be measured only in direct productivities and benefits, because there are indirect and intangible values and other externalities of significant amount.

In *short periods*, where seasonal and particular values of the variables and of the balance between soil, water and plants can cause serious threats to the development and maintenance of forest stands, namely extreme dry or wet seasons or spells, for which significant losses and serious damage to the forest systems may occur.

At episodes or events of short or very short duration, where extreme values of the water content in the soils and other climatic variables, namely relative humidity and temperature, can lead to processes above the thresholds or the bearing capacity of the soil, the land or of the forest systems, which can cause extreme and irreversible damage to the forests, triggering in the extreme, the processes of desertification and the development of forest fires.

Due to these hydrologic constraints it is fundamental to establish a framework for the "optimax" management of the forestlands, based on the right technological management of two of the most important production factors such as soil and water.

The evaluation of the sustainability of the forest systems should be preformed for large time horizons and must take in to account the three time wise hydrological situations, above mentioned. Also, the environmental impact in the soil and water recourses of the region, namely the induction of desertification and other security threats, should be accounted.

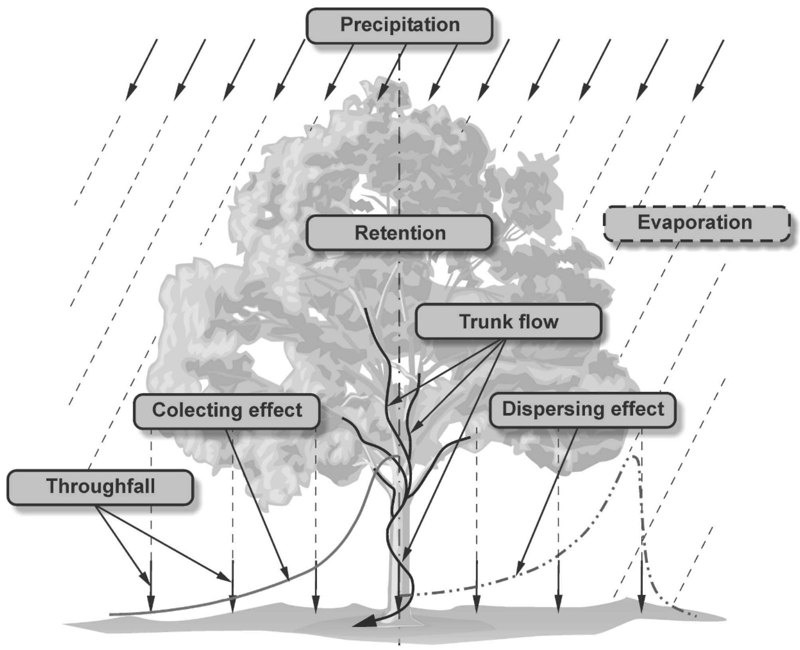

Figure 1. Hydrological behaviour of tree canopies

In the next two chapters some attention is focused in particular components of the hydrological processes for tree canopies and on their effect on the water erosion mechanisms.

HYDROLOGICAL BEHAVIOR OF VEGETATION CANOPIES

Major Processes Components

The major processes related to the hydrological behaviour of trees are presented in Figure 1.

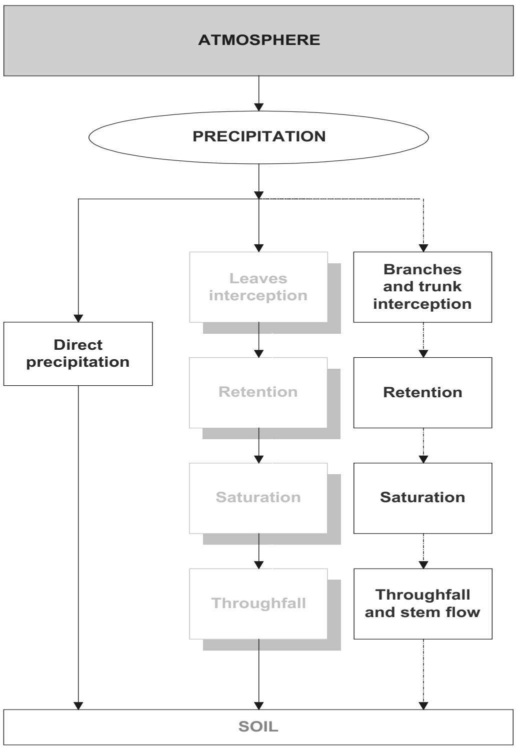

Figure 2. Scheme of rainfall interception and throughfall

To calculate the total amount of rain that is intercepted by the vegetation cover and which is retained at the exposed surface of the tree, it is necessary to model the hydrological behaviour of the vegetation canopies and compute the values of the major components of the hydrological budget, at least on a daily basis.

In Figure 2 it is indicated schematically the mechanisms of rainfall interception and throughfall associated with the vegetation canopies.

Considering a control volume, above the soil surface under the tree cover and including the tree canopy, the relation between throughfall (precipitation under canopy) and atmospheric rainfall is given by the following expression (Antunes, 1995; Coutinho and Antunes, 1999; Coutinho and Antunes, 2000; Antunes and Coutinho, 2003):

$$\mathbf{P = P' + R + T_f + E_v} \tag{1}$$

where:

P - Precipitation;
P’ - Throughfall;
R - Retention;
$\mathbf{T_f}$ - Trunk flow;
$\mathbf{E_v}$ - Evaporation.

The amount of water that reaches the ground is the sum of the throughfall and the trunk flow. The throughfall has two components: one, which is not intercepted, falls through the canopy porosity with the same characteristics of natural rainfall; other, resulting from the rainfall intercepted by the foliage, drips from leaves’ borders. The leaves act, also, as collectors and part of the rainfall intercepted is diverted to the branches and flows down the tree trunk up to the ground.

In general, it is usually considered that, during the rain event, the evaporation rate is of an order of magnitude smaller than those of the other terms, and that trunk flow is only relevant for very intensive rainfall events, so, both are generally neglected. That is not the case for dense vegetation covers or tree species with dense foliage, for which the value of the evaporation depends on many factors, mainly, the amount of foliage retention; however, it is quite difficult to calculate this value with accuracy.

On a daily, or event, basis and for most of the cases, the evaporation can be responsible for abstraction of the total amount of leave's retention, which provides that in the next day, or rain event, the leave’s retention capacity it is free to intercept (and abstract) more rain.

Leaf Retention and Throughfall Data

To obtain accurate data to quantify the hydrologic behaviour of trees, some experimental work was done in Portugal, concerning various forest and orchard trees, where leaf retention and throughfall drops were measured in laboratory conditions. Particular attention has been given to the common oaks of the Mediterranean zone - cork oak (*Quercus suber*), evergreen oak (*Quercus rotundifolia*) and wild oak (*Quercus ilex*) - to pine trees (*Pinus pinea* and *Pinus pinaster*), to orchard trees - olive (*Olea europaea*) and orange (*Citrus sinensis*) - and to Eucalyptus (*Eucalyptus globulus*) which are the most common species used in the agricultural and forest systems in southern Portugal.

The laboratory set up consisted of a very simple rainfall simulator, able to produce different rainfall intensities and rain drops in various diameter ranges' (Antunes, 1995).

The major results obtained for water retention and drop sizes ranges are summarized in the following table, for various leaf sizes' of the different tree species, above mentioned and studied in laboratory.

Table 1. Rainfall retention and drop sizes ranges for leaves of different tree species

tree species	**average water retention (mm)**	**range of throughfall drop sizes' (mm)**
oak species	0.30 to 0.40	4.7 to 6.3
eucalyptus	0.08 to 0.14	3.4 to 4.8
olive trees	0.40 to 0.50	3.7 to 4.1
orange trees	0.45 to 0.55	4.1 to 4.7

Rainfall Interception

The total volume of rainfall intercepted and retained by the tree canopies is the sum of foliage, branches and trunk retention's. Once the maximum initial retention is attained the leaves start dripping and the retention over the exposed surfaces is kept at a stabilized retention level.

The maximum stabilized retention volume can be calculated using the equation:

$$\mathbf{R = r_e\, L + r_W\, W} \qquad (2)$$

where:

R - Total tree retention;
r_e - Specific leaf retention;
L - Leaf surface;
r_w - Specific wood retention;
W - Trunk and branches (wood) surface.

The value of the total leave retention is calculated by the expression,

$$\mathbf{L = C_L\, .\, LAI\, .\, At_c} \qquad (3)$$

where:

C_L - Average leaf aspect coefficient, $\mathbf{C_L = 1/\cos\theta}$,
with θ as the average leaf aspect;
LAI - Leaf area index;
At_c - Soil covered surface.

The aspect coefficient for the leaves surface, $\mathbf{C_L}$, varies, usually, from 1,3 to 6,0 for corresponding aspect angles of 40 to 80º. For instance, the $\mathbf{C_L}$ for Cork oaks can be considered a little less than 2.

For mature Eucalyptus stands the aspect coefficient, $\mathbf{C_L}$ varies, generally, between 5 and 20 for corresponding aspect angles of 70 to 87°. Since both surfaces of the Eucalyptus leaves are exposed to rainfall and can retain water, the total amount of rainfall retention can be in the order of values between 7 and 15 mm, or even higher for well established mature stands, over the covered ground.

Similarly the total surface of the trunk and branches can be computed by:

$$\mathbf{W = C_w\, .\, WAI\, .\, At_c} \qquad (4)$$

The coefficient, $\mathbf{C_w}$ - wood aspect coefficient - present values of an order of magnitude greater than $\mathbf{C_L}$ and the **WAI** - wood area index – in the opposite, is significantly smaller than **LAI**.

The value of **W** is seldom taken in account because it is usually of smaller magnitude than **L**.

Throughfall and Runoff

Throughfall

The total amount of rainfall that falls through the vegetation canopy is the addition of the rain that falls through the pore spaces in the canopy and the one which, being intercepted by the foliage cover drips, from the leaves borders.

To calculate the value of the effective precipitation that reaches the ground, one should add to the throughfall, **P'**, the value of the trunk flow, $\mathbf{T_f}$, as can be seen in Equation 1. However as it was mentioned before, the value is neglected in most of the cases, namely, when the time scales and discretization required are of magnitudes greater than hours or minutes, because trunk flow occurs only in very intensive rainfall events with significant duration.

The values for the foliage retention and throughfall were calculated for some areas with Eucalyptus close to the Mitra's campus of University of Évora, in southern Portugal. Those stands correspond, at the time of the study, to relatively mature and dense plantations with more than eight years of age. These conditions are representative for this type of forest systems in more than two thirds of the period of vegetation development, since the plantation time up to the cutting time for wood or pulp production.

The values presented in Table 2 correspond to the average rainfall, retention and throughfall computed, using a simulation model of the hydrologic behaviour of trees, for the three hydrological years of 1997/1998 to 1999/2000, which are of very significant representation of the average year and for years with precipitation forty percent above and below the average. It was adopted an average specific retention for the tree cover (**R**) of 10 mm.

Table 2. Rainfall, foliage retention, throughfall and runoff, in areas with Eucalyptus globulus, in southern Portugal (with 10 mm of specific retention)

hydrologic year	rainfall (mm)	foliage retention (mm)	throughfall (mm)	runoff (mm)
1997 / 1998	894	544	350	108
1998 / 1999	368	261	107	2
1999 / 2000	550	347	203	41

Runoff

For the above-mentioned periods, daily values of foliage retention, throughfall and runoff were calculated using a simple balance model. The model was run on a daily basis and the surface retention, infiltration, soil storage, evaporation and evapotranspiration were also estimated.

It is important to mention that for the region of Évora, with an average rainfall of about 550 to 650 mm and for the typical land use of "Montado" with cereals, the average runoff in the order of 100 to 120 mm. In more detailed analysis, those values of runoff were only obtained, for the eucalyptus plantations, for rainfall years with total precipitation greater than about 850 mm, like for instance 1997/1998 in Table 2.

EROSION UNDER TREE CANOPIES

Generalized Model

A model was build as a subcomponent of the USLE or RUSLE cover or crop coefficient C. The model considers the overlapping effects of rainfall retention, throughfall erosivity and sub canopy vegetation layer that act as a protection buffer for the soil.

There are two different effects on the erosion processes: one that concerns the hydrological behaviour of the vegetation canopy; and other, that considers the effect of the throughfall drops hitting the ground, which is usually related with the erosivity of rain and the cover protection due to the rain interception. It was adopted to consider these effects grouped together in the C factor.

To explain clearly the different process two situations were considered:

- Single trees, covering bare or cultivated soil;
- Mixed systems, with trees and cereal crops under the trees.

Single tree covers

The crop coefficient, or tree canopy coefficient, C_t, can be calculated by the following expression:

$$\mathbf{C_t = p_L \,.\, C + (1 - p_L) \,.\, t_c \,.C \,.\, C_c} \qquad (5)$$

where:

C_t - Canopy coefficient for single tree;
p_L - Canopy porosity;
t_c - Throughfall coefficient;
C - USLE / RUSLE crop coefficient for sub canopy soil cover;
C_c - Canopy energy coefficient.

with, $t_c = P' / P$ and $P' = P - R$
and, the parameters have the meaning already mentioned:

P' - Average annual throughfall;
P - Average annual precipitation;
R - Average annual tree retention.

The effect of rainfall abstraction due to the rain interception, which is mainly transferred to the atmosphere as evaporation, is considered in the throughfall coefficient t_c.

Mixed system

The total crop coefficient for mixed systems, C_m, with trees and associate agricultural crops can be calculated by the following expression:

$$C_m = (1 - dp \cdot At_c) \cdot C + dp \cdot At_c \cdot C_t \tag{6}$$

where:

C_m - crop coefficient for mixed systems;
C - USLE / RUSLE crop coefficient of the vegetation cover;
dp - number of trees, per unit land surface;
At_c - average surface of the soil's canopy cover;
C_t - canopy coefficient for a single tree.

Throughfall Erosivity

The rainwater drips from the leaves and reaches soil with a distribution that is a function of the architecture of the trees. In Figure 1 it is indicated that the distribution the throughfall may have different patterns – collection or dispersing pattern – according to the tree's species. In the present study, a uniform distribution pattern under the tree's cover was assumed.

In Table 1, the diameters of drop sizes corresponding to the studied tree's species of the Mediterranean region are presented. To evaluate the erosivity of the drops, their kinetic energy must be computed (Coutinho and Antunes, 2000; Antunes and Coutinho, 2003).

The average value of the kinetic energy for the throughfall from vegetation canopies is the throughfall erosivity. The relation between the reference kinetic energy for natural rainfall and the energy for the throughfall for different dripping heights, or average canopy heights, can be considerable as the energy coefficient for the tree cover canopy, related to that drop fall.

The standard or reference kinetic energy of throughfall is defined for average conditions, for a rainfall intensity of 20 $mmhr^{-1}$, with a regular distribution of drop sizes, per unit volume of rain (mm) and unit surface of covered soil (m^2). The reference energy is approximately 20.2 $J.mm^{-1}.m^{-2}$ (Epema and Riezebos, 1983).

In Figure 3, the relation between the energy coefficient, for the tree canopy, and the average dripping height of the canopy is presented. According to the computation, the values can range from 4.5 to 27.8 J. $mm^{-1}.m^{-2}$, respectively, for average drop falls of 0.5 to 5.0 m.

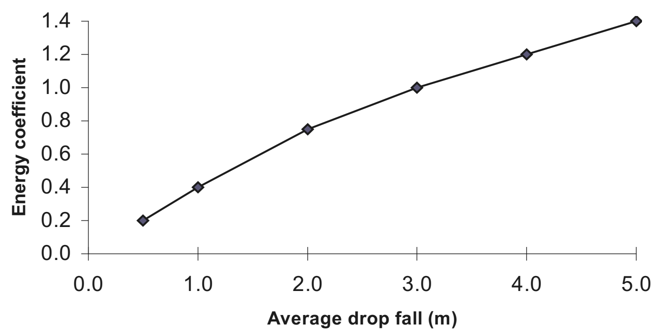

Figure 3. Energy coefficient for tree canopies as a function of average drops fall

It is possible to see that an average falling height of about 3.0 m corresponds to the erosivity of natural rain. For oak species, the erosivity of throughfall dripping water can easily be greater than that of natural rainfall.

Erosion Estimation in Forest Land

The application of the developed model allows the computation of USLE/RUSLE crop coefficient for general situations of mixed agricultural or forestry systems, with association of other land uses.

The overall erosion can then be estimated with the USLE/RUSLE methodology with the application of the developed C factor for trees.

In Table 3, an example of the model application in Southern Portugal is made for a region with an average precipitation of about 600 mm per year, and a mixed cover of wheat and Cork Oak (Montado). An average value of LAI = 4 was considered and the adopted drop fall from the cover was 2.2 m. Different densities of trees, per unit cultivated area were computed.

To emphasize the effect of the controlling erosion under tree canopies a **Conservation factor** was computed. This factor indicates the relation between the protection (level of erosion control) obtained with the reference ground cover vegetation and the protection resulting from both the trees and the same ground cover.

For this "Montado" with tree densities between 40 and 80 tree.ha^{-1} the adjusted USLE cover coefficient for mixed systems, $\mathbf{C_m}$, ranges between 0.34 to 0.28, which correspond to an increment of soil protection, related to the reference ground crop, between 15 to 30%.

Table 3. Crop coefficient for mixed agricultural systems

	dp tree.ha^{-1}	**C_m factor**	**Conservation factor**
No trees	---	0.40	0.00
Montado	2	0.40	0.01
	4	0.39	0.01
	8	0.39	0.03
	10	0.39	0.04
	20	0.37	0.07
	40	0.34	0.15
	80	0.28	0.29
	100	0.25	0.37

CONCLUSIONS

The first conclusion one can draw is that the development of a tool for the detailed analysis of water balances and erosion levels, associated with forest systems, allows their proper management, seeking sustainability and reducing the fragilities toward extreme adverse conditions, which can trigger environmental degradation and desertification processes that constitutes threats to homeland and global security.

For dense forest stands, in particular of trees with large foliage area like Eucalyptus, it is shown that very significant rainfall retention may occur with important impacts in the hydrological balance. This promotes reduction of under canopy vegetation, soil infiltration and storage and on the runoff.

For the studied situation, summarized in Table 2, with annual rainfall less than about 370 mm there is almost no runoff. Also, for average rainfall years the runoff is reduced by about 50 percent of the average runoff for the region; and, only years with rainfall 50 percent greater than the average are able to produce runoff values greater than the regional average value.

In zones with annual values of precipitation less than 600 mm the trees can be submitted to frequent and relevant water stresses, some times for more than one year. In order to get better conditions, at the environment level and economic viability, it is necessary to adopt adequate plantation densities, in Mediterranean areas, as the one of southern Portugal.

The right equilibrium of plant densities is of outmost importance to provide the basic sustainability level, in what water balance is concerned, and to reduce the threat of extreme events, such as forest fires.

In addition to the important role that mixed agricultural systems play in traditional agricultural, namely in the Mediterranean regions, the protection effect of the tree cover can be estimated in a more accurate way. It is, clear that the canopy cover is quite relevant to mitigate erosion and desertification.

From the developed model, one can see that the average dripping height (related to canopy height) is a very important variable to control erosion. It is also shown, that the tendency to increase the canopy clearance, to allow the use of more powerful agricultural machinery, can reverse the effect of protection and being responsible to the increase of erosion rates.

For the case of Montados, it was evaluated the effect of different tree densities in the reduction of water erosion. For about 40 trees per hectare, with cereals, it was estimated a reduction in erosion of about 15%, in relation to the same cereal crop without trees.

As a final remark, it is recognised the need of putting more emphasis in researching in detail the hydrological behaviour of trees and other vegetation covers. This will provide more accuracy in the project of forest systems, better policies regarding the combat to desertification, and lesser threats to the environment and to security, in general.

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PART. VI

Desertification Indicators and Forecasting Techniques

ENVIRONMENTALLY SENSITIVE AREAS AND INDICATORS OF DESERTIFICATION

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ABSTRACT

Desertification is the consequence of a series of important processes in the Mediterranean environments, especially in semi-arid and arid regions, where water is the main limiting factor of land use performance on ecosystems. Among the most important processes of desertification are soil erosion and salinization particularly affecting hilly areas and lowlands, respectively. Various methodologies have been developed in identifying and mapping environmentally sensitive areas (ESAs) to desertification. Studies have shown that the various types of ESAs have different behavior on crop production, plant growth, grazing capacity, and soil erosion rates. For example, olive oil and cereal production decreased as the type of ESA changes from non-threatened to critical areas. Soil erosion measures have shown that soil erosion rates increased as the sensitivity of land to desertification increased. Loss in land productivity greatly affects farmer's income and measures applied for protecting the land from further degradation and desertification.

The necessity of elaborating indicators is one of the priorities identified by the United Nations Convention to Combat Desertification (UNCCD). The use of indicators can generally simplify complex processes and provide appropriate tools for combating desertification. Indicators can be classified to those related a) to the physical environment (soil, vegetation, climate), b) to the land management (tillage operations, irrigation practices, animal density grazing the land, forest fire protection, erosion measures, etc), and c) to the socio-economic characteristics (farmer age, family size, farm size, subsidies, farmer income, etc). Indicators can be better used for defining land desertification risk if they are classified according to the land use type. For example important indicators for defining desertification risk for vineyards are related to land management as well as to land characteristics such as tillage operations, tillage direction, slope gradient, parent material, plant cover, etc. Studies, conducted in areas in which the main process of desertification was salinization, showed that important indicators for defining desertification risk were ground water depth, drainage, water quality, frequency of flooding, distance from the seashore, type of land use, rainfall, etc.

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INTRODUCTION

An assessment carried out by FAO, based on data collected by the project "Global Assessment of Soil Degradation – GLASOD" (Oldeman, 1988; Oldeman *et al.,* 1990), showed that 19,5% of drylands of the world have been affected by soil degradation. The Mediterranean region has been subjected to significant degradation of its natural resources for a long period (Grove, 1996; Thornes, 1996). One of the most important processes of desertification is soil erosion, particularly affecting hilly areas. Salinization is another important process promoting desertification especially in lowlands. In many cases, the rapid development resulted in the over-exploitation of the aquifer systems for a variety of uses, such as agricultural, industrial and domestic, causing gradual intrusion of sea water in the aquifers. Soil salinization is a potential desertification threat for lands characterised by high xerothermic climatic indices (Kosmas, 1999).

Several approaches have been proposed in order to quantify or evaluate soil degradation and desertification. Since 1930's, Storie (as reported by Singer and Ewing, (2000)) has defined an index using a parametric equation of nine factors representing a series of soil characteristics such as soil texture, morphology, sodicity, drainage class and slope gradient. In 1949 scientists have tried to define desertification as the creation of desert-like conditions resulting from erosion processes (Aubreville, 1949). Later other authors (Parr *et al*., 1992; Granatstein and Bezdicek, 1992; Arshad and Coen, 1992; Hornick, 1992) reported soil quality as a function of six specific soil quality elements: plant production, resistance to erosion, groundwater quality, surface water quality, air quality and food quality. Larson and Pierce (1994) proposed the use of pedotransfer functions (Bouma, 1989) to estimate soil attributes which were too costly to measure and to interrelate soil characteristics for evaluation of soil quality. Rubio and Bochet (1998) proposed a synthetic list of criteria, and a procedure for the selection, evaluation and application of indicators for assessing desertification risk. Recatala *et al*. (2002) reported a series of environmental indicators to assess and monitor desertification and its influence on environmental quality in Mediterranean ecosystems.

Having in mind the mentioned difficulties for identifying appropriate indicators of desertification, it is necessary to implement a flexible strategy that takes into account all these problems. The strategy can be based in the following principles (Lopez-Bermudez and Barbera, 1998): (a) exploitation of easily available information, (b) characterization of desertification at regional scale in a first step and later at local scale, (c) selection of indicators most directly related to the problem, (d) considering singularities of agro-ecosystems, (e) utilization of indicators that link biophysical aspects to socioeconomic ones, and (f) emphasizing those aspects more relevant from the socio-economic point of view. Empirical methodologies for estimating and mapping soil erosion and land degradation have been developed. Soil erosion maps have been compiled for specific areas (De Ploey, 1989; Montier *et al*., 1998) or for southern Europe (CORINE, 1992) by using various parameters considered important for soil erosion.

DEFINITION OF ENVIRONMENTALLY SENSITIVE AREAS

Environmentally Sensitive Areas (ESAs) to desertification around the Mediterranean region exhibit different sensitivity to desertification for various reasons (Kosmas *et al.*, 1999). For example there are areas presenting high sensitivity to low rainfall and extreme events due to low vegetation cover, low resistance of vegetation to drought, steep slopes, highly erodible parent materials, etc. High sensitivity can be also related to the type of land use, since land use can promote desertification in climatically and topographically marginal areas. Four general types of ESAs have been distinguished based on the stage of land degradation (Kosmas *et al.,* 1999):

- Critical ESAs: Areas already highly degraded through past misuse, presenting a threat to the environment of the surrounding areas, i.e. badly eroded areas subject to high run-off and sediment loss. This may cause appreciable flooding downstream and reservoir sedimentation. Critical ESAs are subdivided in three sub-types C3, C2, and C1, in a decreasing stage of land desertification.
- Fragile ESAs: Areas in which any change in the delicate balance between natural and human activity is likely to bring about desertification. For example, the impact of predicted climate change due to greenhouse effect is likely to enhance reduction in the biological potential due to drought causing areas to lose their vegetation cover, be subject to greater erosion, and finally shift to a critical ESA. A land use change, as for example, (a shift towards cereals cultivation,) on sensitive soils might produce immediate increase in run-off and erosion, and perhaps pesticide and fertilizer pollution downstream. This type of

ESAs are subdivided in three sub-types F3, F2, and F1 in a decreasing stage of land desertification.

- Potential ESAs: Areas threatened by desertification under significant climate change, if a particular combination of land use is implemented or where offsite impacts will produce severe problems elsewhere, for example pesticide transfer to downslope or downstream areas under variable land use or socio-economic conditions. This would also include abandoned land which is not properly managed. These ESAs are in less severely desertified stage than fragile ESAs, for which nevertheless planning is necessary.
- Non Threatened ESAs: Areas with deep to very deep soils, nearly flat, well drained, coarse-textured or finer textured soils, under semi-arid or wetter climatic conditions, independently of vegetation, are considered as being non-threatened by desertification.

The various types of ESAs to desertification can be distinguished and mapped by using certain key indicators or parameters for assessing the land capability to withstand further degradation, or the land suitability for supporting specific types of land use. A simple methodology has been developed by Kosmas *et al.* (1999) to identify ESAs to desertification by using 15 simple indicators related to soil, climate, vegetation, and land management characteristics. After the definition of classes and the assignment of weighing indices for each indicator, soil quality, climate, vegetation and management are defined by combination the various indicators. Then the ESAs are identified based on these qualities (Kosmas *et al*., 1999). This approach includes parameters which can be easily found in existing soil, vegetation, and climate reports.

THE PHYSICAL MEANING OF “ESAS”

The above mentioned methodology for defining and mapping ESAs to desertification can be used to assess the impacts of desertification on crop production, plant growth, grazing capacity and soil erosion rates. Studies conducted in areas affected by desertification in Greece in land use types representative for the Mediterranean region such as olive groves, cereals, vineyards, pastures and pine forests showed significant changes in land productivity. The average olive oil production decreased from 1293 kg ha^{-1} to 430 kg ha^{-1} as the type of ESA changed from non-threatened to critical areas (Tsara *et al*., 2003 submitted for publication). Wheat grain production increased from 1710 kg ha^{-1} in critical-C3 to 4800 kg ha^{-1} in potential ESAs.

Leaf area index (LAI) values measured in olive groves and pine forests decreased to about one half as the type of ESA changed from potential to critical. The average LAI values in non-threatened ESAs were 1.9 and 1.4 in pine forests and olive groves, respectively (Tsara *et al*., 2003 submitted for publication).

In a study conducted in pasture lands in Greece, no relation was found between the number of animals and land grazing capacity or between the number of animals and stage of land desertification. The annual amount of animal feed supplied in excess to the palatable grass grazed by the animals decreased to about 20% as the sensitivity of the land to desertification decreased.

Critical areas to desertification are usually severely eroded, while fragile or potential areas are moderately to slightly eroded. The average sediment loss due to surface water runoff estimated by the PESERA soil erosion model (Kirkby *et al*., 2000) was clearly related to the type of ESA. Average sediment losses of 0.02 t ha^{-1} $year^{-1}$, 0.16 t ha^{-1} $year^{-1}$, and 5.74 t ha^{-1} $year^{-1}$ have been estimated for potential, fragile, and critical ESAs to desertification, respectively.

SELECTION AND CLASSIFICATION OF INDICATORS

As it has been recognized by several national and international organizations, indicators are playing an increasingly important role in supporting development policies for protecting land from desertification. Indicators can become a valuable tool for land users or policy makers if certain criteria are met. Riley (2001) and Stein *et al*. (2001) have defined the following basic selection criteria for using indicators:

(a) objectively and scientifically measurable.
(b) preferentially quantitative.
(c) easy and cost-effective to be measured.
(d) sensitive to environmental changes.
(e) simple in concepts.
(f) able to support policy decisions.

The European Environmental Agency (EEA) has considered that an indicator can be defined as a parameter or a value which provides information about a phenomenon (OECD, 1993; EEA, 1998).

Many authors (O' Connor, 1994; Pieri *et al.*, 1995; SCOPE, 1995; Dumanski and Pieri, 1996) considered that classification of indicators must take into account the linkages between; (a) pressures exerted on the environment by human activities, (b) changes in quality of the environmental components, and (c) societal responses to these changes that can be a useful and valuable tool for land-users and policy makers. In this sense, the DPSIR framework (Driving forces, Pressure, State, Impact, Response) has been proposed (Figure 1).

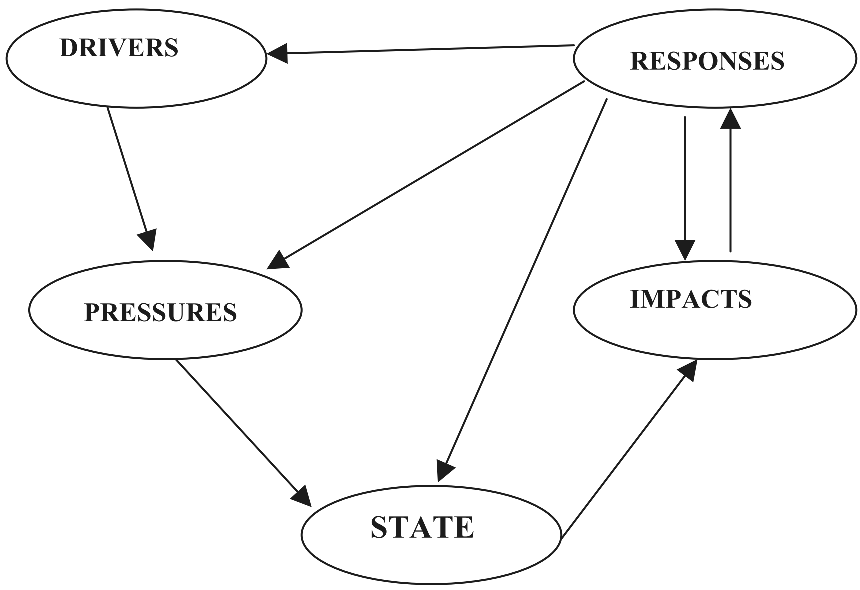

Figure 1. DPSIR framework for system conditions used for classifying indicators (EEA, in Gentile, 1998)

Indicators can be also classified based on the level of interest (local or regional) or on their origin (physical environment, management, social, economic). As Arshad (2002) states, a genuine discussion between scientists and land-users is very important in identifying appropriate indicators. Scientists have to take into consideration the experience and the knowledge on environmental issues of local land users and stake holders. A series of indicators related to soil, climate, vegetation, water, management, society, economy and policy has been identified and given to various people to classify according to their importance on land desertification in Greece (Kosmas, unpublished data). As Figure 2 shows, rainfall, slope gradient, number of animals grazing the land, soil depth, type of vegetation and water available have been considered as the most important indicators of desertification.

Similar studies conducted in Portugal, Spain and Italy showed different results. This can be attributed to the different people perception on how desertification affects their land and what the impacts are on their life.

INDICATORS AND "ESAS"

Various studies have been shown that indicators are related to the type of ESAs. As an example can be given a detailed study conducted in Greece during the execution of the European Union research project DESERTLINKS. The study was conducted in the island of Lesvos and in the areas of Thiva and Farres located in the central part of the mainland of Greece in proximity to Athens. A series of candidate indicators related to the physical environment, social, economic, and management characteristics were selected such as family status, land tenure, present and previous land use types, period of existing land use type, application of fertilizers and pesticides, tillage operations, tillage depth and direction, water availability, water quality and quantity, sustainable farming, soil erosion control measures, controlled grazing, soil water conservation, subsidies, etc. Based on existing classification systems such as the georeferenced database, classes defined for each indicator and presented in a tabulated form. In collaboration with the land user, data were collected for the studied indicators from 327 field sites under various land use types.

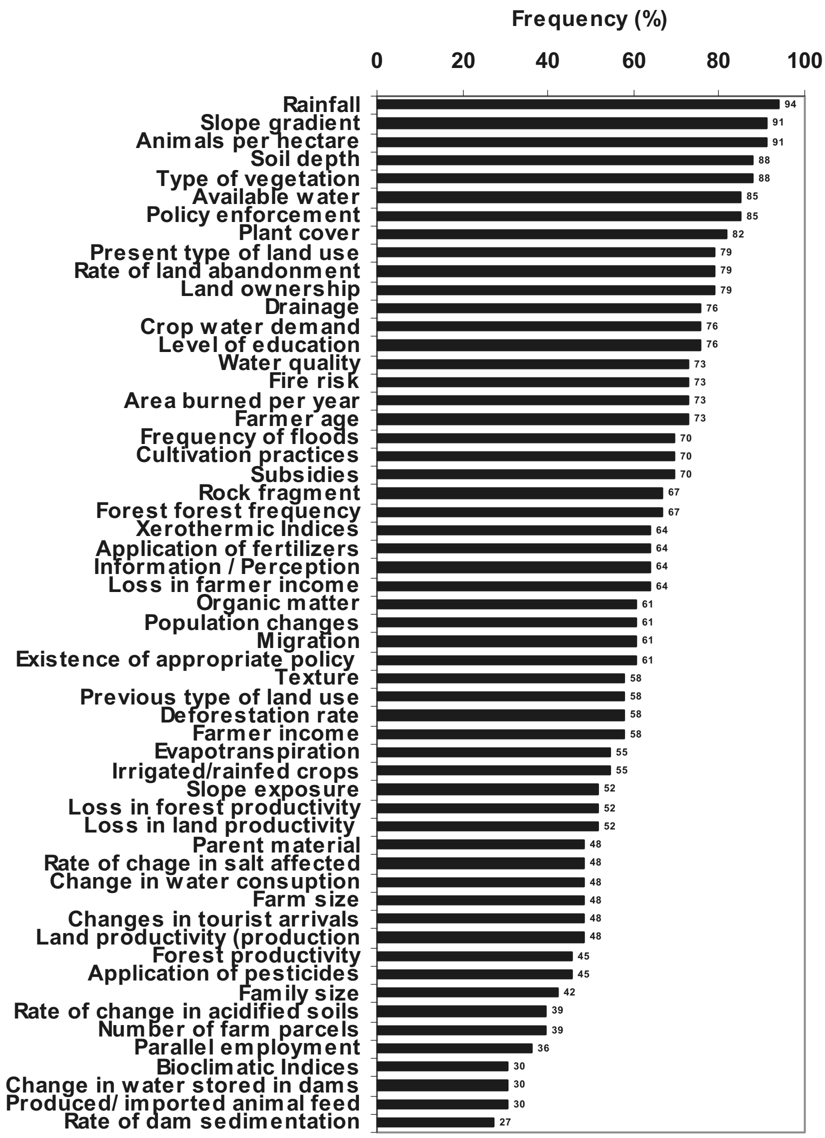

Figure 2. Rating of indicators with respect to the importance to desertification by various people (Kosmas, 2003)

The island of Lesvos is divided to three regions, Mithimna, Plomari and Mytilini (Figure 3). The region of Mytilini includes the less sensitive areas to desertification. 65.9% of this region is characterized as fragile and only 13.8% as critical to desertification. Non-threatened and potential ESAs comprise 8.9% and 10.1% of the land, respectively. The largest part of Plomari region is characterized also as fragile (69.9%), and almost the remaining as critical (27.4%) to desertification. The region of Mithimna is the most degraded part of the island. An area of 53.1% is characterized as critical to desertification, while 39.3% as fragile.

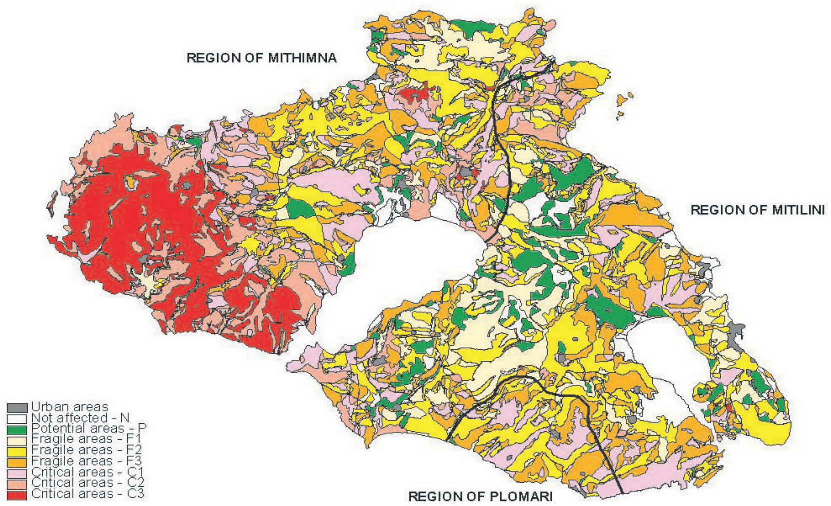

Figure 3. Map of environmentally sensitive areas to desertification of Lesvos (Kosmas *et al*., 1999)

Population can be considered as a regional indicator. According to the 2001 general census, the island of Lesvos had 90,663 people. The distribution of population in the regions of Mithimna, Mytilini and Plomari was 23,046, 60,775 and 6,842, respectively. Therefore, 67% of the total population of the island is concentrated in the region of Mytilini. The population of Mithimna and Plomari regions is undergoing a continuous decrease mainly due to migration to urban areas, including Mytilini. The low population densities in the region of Mithimna compared to the other regions can be attributed to the poor land conditions present in this region. As Figure 4 shows, the population density has changed from 0.52 in 1940 to

0.28 (people/ha) in 2001, while in the regions of Plomari and Mytilini the population density has changed from 1.26 to 0.50 and from 1.07 to 0.87 for the same period, respectively. The change in local population of Plomari region is mainly attributed to adverse climatic conditions, decline of the local industry, and degradation of natural resources.

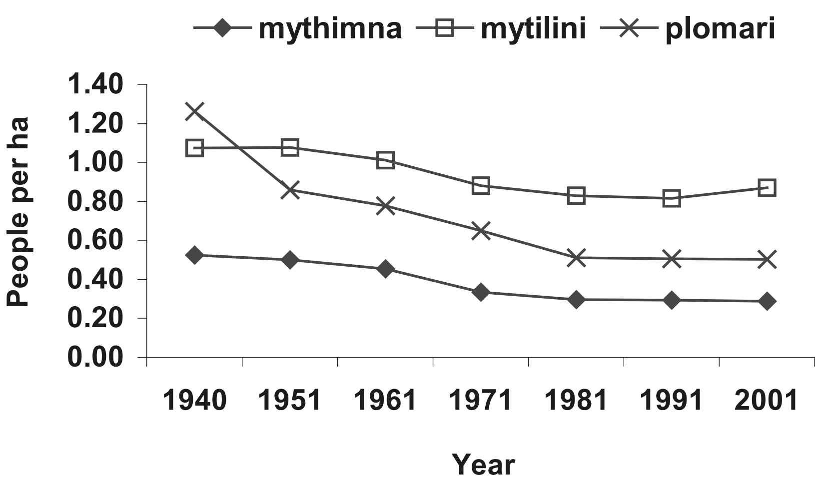

Figure 4. Changes in local population density with time in the regions of Mithimna, Plomari, and Mytilini of the island of Lesvos (Kosmas *et al*., 2002)

In the opposite, the number of animals in the island of Lesvos, including sheep and goats, increased between 1950 and 1998, from 120,293 to 353,940, respectively. A significant increase in animals occurred after 1979 due to connection of Greece with European Union. The rate of increase was even higher after the allocation of subsidies. As Figure 5 shows, the animal density increased from 0.74 (animals/ha) in 1920 to 2.81 in 1998 in the region of Mithimna, while the corresponding values for the regions of Mytilini and Plomari were 0.43 (animals/ha) in 1920 and 1.55 in 1998 (Figure 5). Therefore, the region of Mithimna, the most degraded area, is undergoing a heavy pressure on the natural resources further deteriorating the problems of desertification.

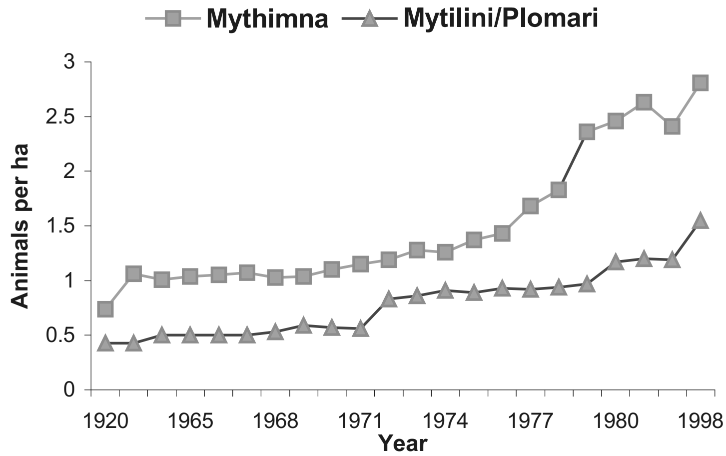

Figure 5. Changes in animal population in the regions of Mythimna and Mytilini-Plomari of the island of Lesvos (Kosmas *et al*., 2002)

The analysis of indicators related to local conditions showed that indicators related to the social characteristics such as family size, land ownership, farmer age, farm size, parallel employment are highly variable among various areas. Important land management indicators related to the stage of land desertification can be considered tillage operations, water availability, sustainable farming, land terracing, storage of water runoff, soil erosion control measures, and soil water conservation.

As Figure 6 shows, land ownership is affected by: (a) the type of ESA and (b) the proximity to a major city. The majority of the land in the island of Lesvos is rented contrary to the area of Thiva and Farres, where the land is mainly private. The low productivity of the land in critical ESAs has resulted in lower farmer income. Under such conditions, people have to abandon the land and migrate to urban areas for a better life. The abandoned land is then rented to other local farmers remaining in the area. On the contrary, critical areas in Thiva with low productivity continue to remain under the control of the land owner since there are more opportunities to gain money through other activities such as parallel employment to industry, multiple choice of products of high value and others.

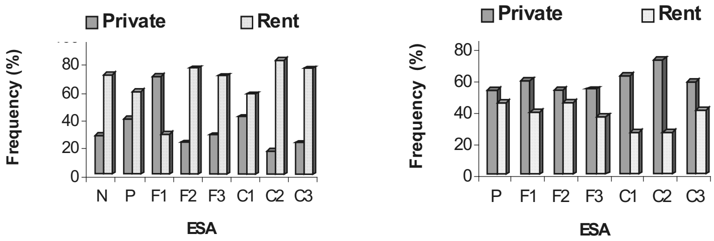

Figure 6. Frequency of appearance of land ownership type in different ESAs in the island of Lesvos (left) and in Thiva and Farres (right) (N=non-threatened areas, P=potential ESAs; F1, F2, F3=fragile ESAs; C1, C2, C3=critical ESAs) (Kosmas *et al*., 2002)

Application of fertilizers in the various types of ESAs can be beneficial for protecting the land from soil erosion, land degradation and desertification. Fertilizers, of course, can have a strong negative effect on water pollution with nitrates and phosphates. When fertilizers are applied biomass production can be higher (if no other factors are limited) and therefore plant cover can be higher, protecting the soil from erosion. Furthermore, by applying fertilizers, higher amounts of plant residuals are expected to be incorporated into the soil favouring better soil structure development. As Figure 7 shows, the frequency of appearance of fertilizer application increased as the sensitivity to desertification decreased in the island of Lesvos. The productivity of critical areas susceptible to desertification is usually low and the land is usually used for pasture; farmers avoid the use of fertilizers. In the opposite, in critical areas to desertification cultivated with cereals in Thiva and Farres, farmers used to apply high amounts of fertilizers.

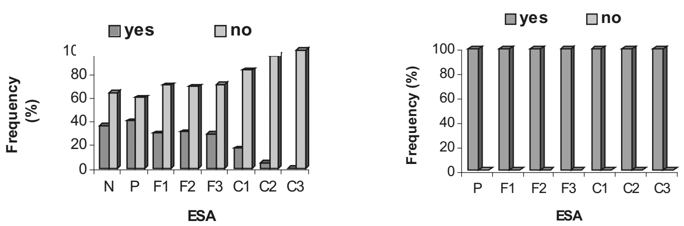

Figure 7. Frequency of appearance of fertilizer application in the various types of ESAs in Lesvos (left) and in Thiva and Farres (right) (Kosmas *et al*., 2002)

Tillage operations in the various types of ESAs are related to land use type, land characteristics, and land management. As Figure 8 shows, areas under pasture are rarely cultivated due to: (a) steep slopes, (b) limited soil depth, (c) high amount of rock fragments and (d) presence of bedrock outcrops and generally low land productivity. The majority of the olive groves are not cultivated due to: (a) steep slopes, (b) presence of terraces that usually restricts traffic-ability. In the opposite, in areas cultivated with cereals, it is obligatory at least one ploughing per year for preparing seedbed. Ploughing of the olive groves in hilly areas is not recommended for protecting the land from soil erosion. Tillage operations are processes that favour soil erosion under certain conditions and they must be considered as pressure on the land for degradation and desertification.

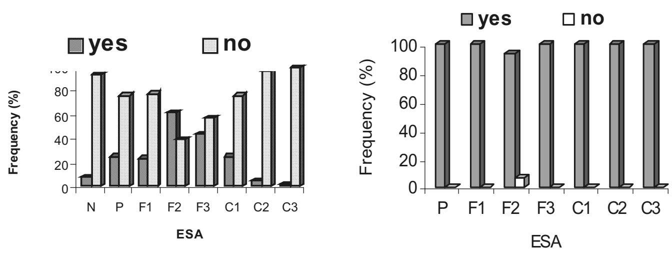

Figure 8. Frequency of appearance of tillage operations versus ESA types in Lesvos (left) and in Thiva and Farres (right) (Kosmas *et al*., 2002)

Policy enforcement on protection of the environment generally decreased as the sensitivity of the land to desertification increased (Figure 9). Critical ESAs corresponding mainly to pastures are not adequately protected. Overgrazing, burning of the natural vegetation, and lack of erosion control measures lead to land desertification. However, some fencing for animal grazing is observed especially in cases of large farms. On the other hand, fragile ESAs, correspond mainly to olive groves and pine forests are relatively adequate protected by: (a) land terracing, (b) minimum or no tillage, (c) forest fire protection, (d) ploughing the soil parallel to the contour lines, etc. Measures of environmental protection in ESAs cultivated with cereals are highly limited.

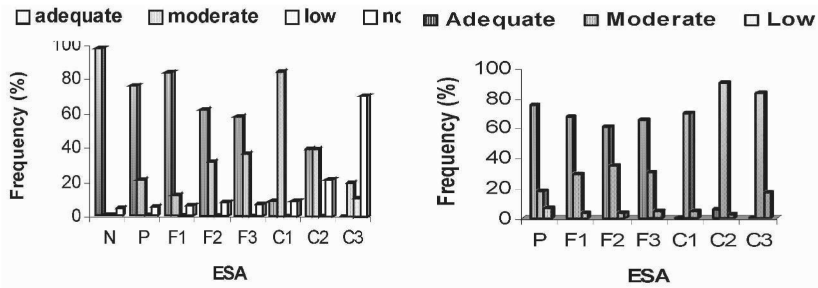

Figure 9. Degree of policy enforcement in the various types of ESAs in olive groves, and pastures (left) and cereals (right) (Kosmas *et al*., 2002)

INDICATORS AND DESERTIFICATION RISK

As was discussed previously, indicators can be used both to identify and map ESAs to desertification and to assess desertification risk under certain physical environmental and management characteristics. The analysis of indicators becomes more effective if land is classified according to the land use type. Based on the criteria for defining indicators discussed previously, candidate indicators related to desertification have to be selected. Distinct classes and weighing indices have to be assigned in each indicator based on existing classification systems and scientific knowledge. Such an analysis have been conducted in areas sensitive to desertification in Greece during the execution of the European Research project DESERTLINKS. Four categories of desertification risk have been identified (high, moderate, low and none) based on the type of ESA and the degree of soil erosion (Tsara e*t al.,* 2003, submitted for publication). Studies have been conducted in the following land use types which are representative for the Mediterranean region: olive groves, vineyards, cereals, pine forests, deciduous oak forests, and salt affected areas independently of land use type. A short discussion follows, as an example, showing how indicators can be used for defining desertification risk in vineyards and salt-affected areas.

Vineyards

Fifty two indicators have been identified in vineyards related to soil, water, climate, topography, management, social and economic characteristics. Emphasis has been given to indicators affecting management quality, such as cultivation of the land (used implements, plough depth, direction of cultivation, etc.), overuse of shallow soils, grazing density, terracing of land and maintenance of terraces, irrigation, (water quality and quantity), erosion control measures, etc. Data were collected in field campaigns in colabaration with the land user. The statistical analysis of the data showed that the most important indicators defining desertification risk in vineyards are related to land characteristics and land management (Figure 10). Among the most important indicators related to land management are frequency of flooding, tillage operations, tillage direction, and policy enforcement. As the frequency of flooding decreased, desertification risk increased. This is important for the lowland areas in which flooding from the upper hillslopes contribute to the increase of soil water stored in the subsoil. Tillage operations increase tillage and surface water runoff erosion and therefore desertification risk increase for the hilly areas. In case that tillage direction is parallel to the contour lines or in the upslope direction desertification risk decreases as compared to the downslope tillage direction. Desertification risk is high in cases that policy enforcement on protection of hilly areas from erosion is absent.

Among the social indicators analyzed, farmer age was found important in the study areas. Desertification risk increased as farmer age increased since management practices protecting the land were reduced.

Important indicators related to the physical environment of the study areas are aridity index, plant cover, slope gradient, parent material and rock fragment content in the soil surface (Figure 10). As aridity index increases desertification risk increases since growth of vines and annual grass is reduced favouring soil erosion. Annual vegetation growing during the winter period, when no leaves are found in vines, can have a beneficial effect in protecting soil from erosion and reducing desertification risk. As slope gradient increases desertification risk increases since soil erosion rates are higher in steep slopes. Desertification risk increases as the parent material changes from alluvial deposits, marl, and limestone. Finally, rock fragment content on the soil surface can have a beneficial effect in protecting the land from desertification since soil erosion and soil water evaporation is reduced.

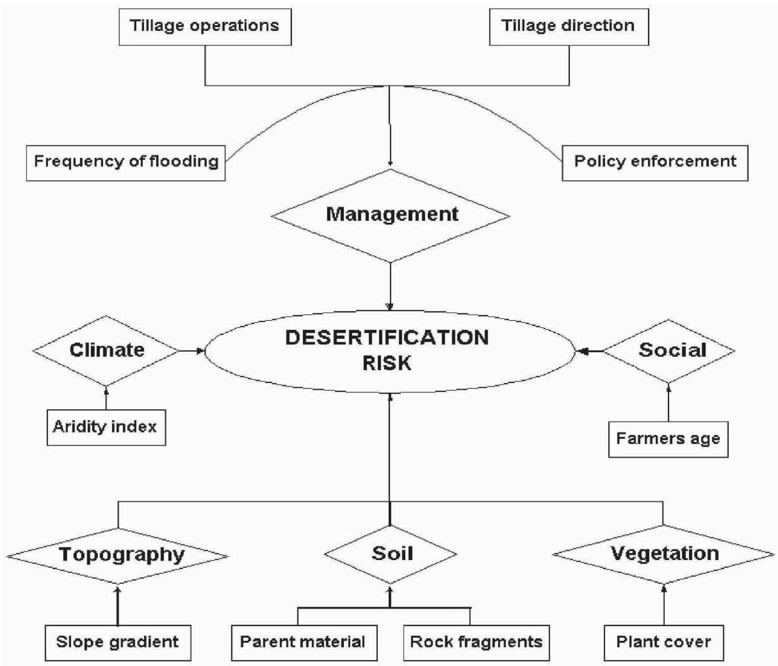

Figure 10. Indicators related to desertification risk in vineyards (Kosmas *et al*., 2003)

Desertification risk (DR) can be assessed by combing the indicators presented in Figure 10 in the following multiple linear regression equation obtained by the statistical analysis of the data: DR=-0.70+0.40FA + 0.73TO - 0.32TD - 0.40PC + 0.98SG + 0.47 PM - 0.54RF + 0.28AI - 0.26FF + 0.83PE. Where: FA is farmer age, TO is tillage operations, TD is tillage direction, PC is plant cover, SG is slope gradient, PM is parent material, RF is rock fragments content on the soil surface, AI is aridity index, FF is frequency of flooding, and PE is policy enforcement of existing regulations.

Salt-affected areas

Salt-affected areas are mainly located in lowlands along the coastal lines. Such areas are very sensitive to desertification due to salinization under specific land and management characteristics. The analysis of the data showed that important indicators for defining desertification risk are related to land management, climate, soil, topography, and water (Figure 11). Important indicators related to management characteristics are frequency of flooding, land use type, and efficacy of reclamation. As the frequency of flooding increases desertification risk increases. Frequency of flooding is also related to other important indicators such as topography and depth of ground water. Desertification risk decreases as land use type changes from pasture, wetland, recreation area, and agriculture. Reclamation of salt-affected areas was mainly related to the presence of a drainage network in the study field sites. As the efficacy of reclamation increased due to lowering of ground water increased desertification risk decreased.

Other important indicators defining desertification risk in salt-affected areas are: distance from seashore, elevation, water quality, ground water depth, drainage and rainfall. Desertification risk increases as the distance from seashore and elevation decreases. Good ground water quality decreases desertification risk. The worse the soil drainage conditions are the higher the desertification risk. In addition, the shallower the ground water table the higher the desertification risk. Reduction of annual rainfall increases desertification risk. Rainfall greatly affects the rate of soil salinization. Soils in areas with rainfall less than 300 mm are usually highly salinized (Imeson, 1995).

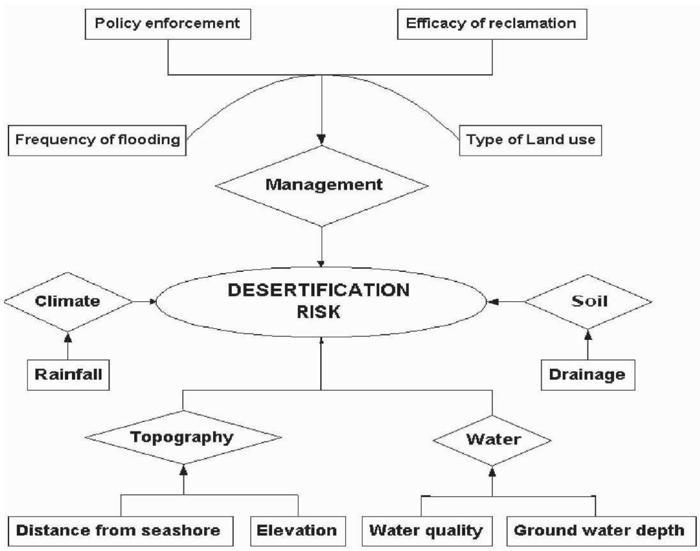

Figure 11. Indicators related to desertification risk in salt-affected areas (Kosmas *et al.*, 2003)

The various indicators presented in Figure 11 can be combined in the following multiple linear equation for assessing desertification risk (DR): DR=6.5-0.25PU+0.23SD-1.16AR-0.29E-0.11WQ-0.35WD+0.33FF-0.41RS+0.84PE. Where: PU is present land use type, SD is soil drainage, AR is annual rainfall (mm), E is elevation (m), WQ is ground water quality, WD is ground water depth (m), FF is frequency of flooding, RS is reclamation of affected soils, and PE is policy enforcement of existing regulations.

In conclusion, among the 52 studied indicators rainfall and policy enforcement are the most important included in the regression analysis for the majority of land use types. The highest weighing index for rainfall corresponds to cereals since the growth is largely depended on the amount rainfall. The indicators, soil depth, slope gradient, and slope exposure are important for the majority of the study land use types. Soil depth was not included in the regression model for pastures, because the majority of the study field sites had shallow soils. Deep soils in the study area are usually used for other land uses such as olive groves, annual crops etc. Slope gradient and slope exposure were not included in the analysis of indicators for cereals since these variables were highly interrelated with soil depth. Policy enforcement of existing regulations on environmental protection was not important for pine forests since the land was fully controlled by public administration.

CONCLUSIONS

The various types of ESAs to desertification have a great impact on land productivity and soil erosion rates. Wheat grain or olive oil production is very limited in critical ESAs and not economically feasible. A low productivity agricultural land is usually converted to pastures with adverse consequences for further soil degradation and desertification under mismanagement conditions.

Simple indicators related to the physical environment, land management, social and economic characteristics can be used in defining land desertification risk. Indicators related to social and economic characteristics can not be easily generalized. They are important for local conditions. Policy enforcement on environmental protection and rainfall have been found as the most important indicators largely affecting desertification risk. Other important indicators are tillage operations, slope gradient, plant cover and land use intensity. The use of indicators for assessing desertification risk becomes more effective if land is classified according to the land use type. In agricultural land use types indicators related to land management are the most important for defining desertification risk. In natural areas the most important indicators for assessing desertification risk are related to the physical environment.

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DESERTIFICATION IN NORTHERN MOROCCO DUE TO EFFECTS OF CLIMATE CHANGE ON GROUNDWATER RECHARGE

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ABSTRACT

Groundwater resources in Morocco are expected to shrink in the next decades due to an increasing withdrawal for rural and urban development, and a decreasing internal recharge by precipitation under the influence of climate change. The objective of this work is to analyse the recharge of groundwater systems in a region with traditional agriculture and current transformations in northern Morocco (Sehoul region) in response to future climate change and land degradation. Models were used to simulate climate change and effects on surface runoff and groundwater recharge. The climate models indicated increases in temperature and decreases in precipitation in all seasons in 2050 compared to 1990, and an increasing variability of autumn precipitation. Because most cultivated fields are freshly ploughed and sown in autumn, this will increase the risk of desertification due to declining groundwater recharge and increased surface runoff and erosion. This is confirmed by the results of the event-based surface runoff simulation for the 2050 climate. Surface runoff is mainly produced in ancient grazing fields and fallow fields. In view of the current transformation of collective grazing fields into cultivated land, problems with loss of rainfall in surface runoff and soil erosion could be mitigated by 1. early tillage of cultivated fields along the slope contour, followed by leveling, 2. locating cultivated fields downslope of grazing fields to enable the capturing of diffuse surface runoff coming from the grazing fields, and 3. leaving fallow fields untilled and covered with crop remnants.

The groundwater modeling results indicate a decrease of the annual groundwater recharge by rainfall of 40-68% from the climate centered in 1990 to the climate centered in 2050. As a result, groundwater levels are predicted to fall up till 2005, but the results are unreliable due to model errors. However, the decreases in precipitation, infiltration and

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groundwater recharge predicted in this study may be expected to add to the observed trend of groundwater level decrease in the study area, and to continuing desertification.

INTRODUCTION

In Morocco, about 4 km^3 of groundwater is exploited per year, on a total of 29 km^3 internal renewable water resources (Ait Kadi, 1998; AQUASTAT, 2002). Of the total water withdrawal in 2000, 90% was used for agriculture (mostly for irrigation), 8% for domestic use, and 2% for the industry (AQUASTAT, 2002). The agricultural sector is important for the Moroccan economy. It contributes 15-20% of the GNP, it is the largest employer in the country, and accounts for one third of the export (Laouina, 2002). At the same time, the provision of drinking water lags behind, especially in rural areas, where half of the population lives. Barely 32% of the rural population has access to safe and reliable supplies of water (Ait Kadi, 1998; Laouina *et al*., 2000), compared to 80% of the population in urban areas (MATUHE, 2001; UNDP/GEF, 2002). Intra- and even inter-regional transport of water is increasingly required to meet the demand for drinking water in urban areas. Therefore the sustained availability of groundwater resources is vital for the country.

However, as a result of rising demands for withdrawal by the expansion of irrigated areas (Laouina, 2002) and urban development (Ait Kadi, 1998), the total internal renewable total water resources per capita fell from 1197 m^3/year in 1990 (Margat, 1995) to 936 m^3/year in 2001 (AQUASTAT, 2002; UN Secretariat, 2002), and are expected to fall to 632 m^3/year in 2025 (Margat and Vallée, 1998).

The decrease in precipitation throughout the southern Mediterranean region in the last decades of the past century aggravates the economic pressure on water resources. A relationship of this trend with global warming is suspected. Several global circulation models suggest that the region will continue to suffer from desertification in the next 50 years (Ragab and Prudhomme, 2000). According to the national communication at the UN Convention on Climate Change in 2001, the climatic prospects indicate an increase of the annual temperature in Morocco by 0.6 to 1.1° between 2000 and 2020. Prospects for the annual precipitation are a reduction by 4% in 2020 compared to 2000. The number of intensive rain storms is expected to increase, and more precipitation will be concentrated in the winter season (MATUHE, 2001). As a result, desertification and structural drought problems are foreseen for the Maghreb countries. Drought is already a structural problem in Morocco, entraining deficits in river runoff and groundwater recharge (Mokssit and El Khatri, 1995). Adding the effect of the foreseen climate change, the available water volumes are expected to shrink by 10-15% of the actual volumes in 2020 due to the falling groundwater levels and the reduction of the storage capacity of dammed lakes by siltation (MATUHE, 2001). The exploitation of yet unemployed renewable water resources will become increasingly difficult and costly.

In addition to climate change, land degradation threatens the recharge of groundwater systems in Morocco. This land degradation is intricately linked to agricultural transformations actually taking place in Morocco, causing an increased pressure on the cultivated area, grazing fields and forests, and deficient management of their natural resources (Laouina, 2001; Chaker, 2001; Nafaa, 2001; Nafaa, 2002). These transformations include the growth and ageing of the rural population, the increasing complexity of landownership (number of regulations, predominance of smallholdership, scattering of fields due to heritage, an increasing number of entitled to common fields), and the urbanisation of high-quality agricultural land surrounding urban areas (Laouina, 2002). In addition, the traditional small-holder agriculturalist is marginalised in favour of modern, large-scale agriculture, whereas the latter is mostly responsible for the inefficient use of water, the pollution of soils and groundwater, and the salinisation of irrigated land (Laouina, 2001).

The deforestation and the extension of the cultivated area date from the beginning of the 20th century. The limits of most of the forests were fixed in the years 1920-1930, but inside the forests and in the remnant pastures, degradation by overgrazing and wood gathering still continues. In the cultivated area the reduction of the surface and shortening of the period in fallow, the mechanisation and tillage in the direction of the slope cause an ongoing land degradation due to the thinning of soils, crust formation and compaction. At the same time, the increasing runoff over the land surface causes soil erosion and the silting and pollution of dammed lakes, which play an important role in the regulation of water provision in the dry season (Laouina, 2001). These problems are not limited to the region southeast of Rabat, but pertain to other mountainous and semi-arid areas in Morocco as well, like the pre-Rif mountains (e.g. Laouina *et al*., 2000; Bouslihim, 2002; Moufaddal, 2002; Moukchane, 2002).

In conclusion, groundwater resources in Morocco are expected to shrink in the next decades due to an increasing withdrawal for rural and urban development, and a decreasing internal recharge by precipitation. Whereas the increasing withdrawal is testified by national development reports and statistics, there is no scientific evidence yet of a decreasing recharge of the groundwater tables in Morocco due to climatic change and land degradation. The objective of this work is to analyse the recharge of groundwater systems in a region with traditional agriculture and current transformations in northern Morocco (Sehoul region) in response to future climate change and land degradation. The elements of land degradation considered in this study are infiltration and surface runoff in degraded grazing areas versus cultivated areas.

Climate change impacts were modelled using dynamical downscaling of the results from the Melbourne University General Circulation Model (MUGCM) (Simmonds *et al.*, 1988; Simmonds and Lynch, 1992) to the Pennsylvania State University/National Center for Atmospheric Research Mesoscale Meteorology Model MM5 (Dudhia, 1993; Grell *et al*., 1994).

A double-scale approach was chosen to handle the different temporal and spatial scales of infiltration and surface runoff and the behaviour of the upper groundwater system. The influence of climate change and land degradation on infiltration and surface runoff was analysed for a small catchment (68 ha) by studying the hydrological behaviour of the catchment at the scale of individual rainfall events. Infiltration and surface runoff were modelled for the climate in 1990 and 2050 and for land use scenarios with current and reduced grazing areas using the LISEM hydrological catchment model (Jetten, 2002). The behaviour of the groundwater system under a reduced recharge from precipitation was analysed using a groundwater flow model conditioned to well levels and abstraction rates for agricultural, domestic and public use observed in a 18*19 km^2 area.

SITE DESCRIPTION

The small catchment analysed for infiltration and surface runoff (the Matlaq catchment) is located in the province of Sala al Jadida, community of Sehoul, about 15-20 km south-east of Rabat (Figure 1). The catchment measures 68 ha. The main channel carries no water in dry weather. Land use consists of rainfed wheat, barley and oats, maize and garden beans in rotation with grazing. Five artificial wells are found in the catchment, located both on the hill summits and in the valley bottom.

The area considered in the analysis of groundwater systems (the Sehoul Plateau, Figure 1) is located between the highway from Rabat to Fès in the north, and the Grou River in the south. Land use consists of rainfed wheat and maize, horticulture (mint, beans), figs and cork oak.

Both the Matlaq catchment and the Sehoul Plateau form part of the Atlantic Meseta. The substrate consists of Paleozoic schists and sandstones, covered from bottom to top by Miocene molasse, Miocene marls and Pliocene calcretes, locally replaced by alluvial terraces consisting of pebbles, sands and clays (Figure 2).

The main regional groundwater system is contained in the Pliocene calcretes (the Mamora aquifer) (Figure 2). Due to the dipping of the Sehoul Plateau to the north, the calcretes thin out in the south, and the volume of the aquifer is less important here. A second groundwater system is contained in the Miocene molasse formation, on top of the Paleozoic substrate (the Miocene aquifer). Following the dip of the Sehoul Plateau, this aquifer deepens to the north and reaches the surface south of the Bou Regreg River, where it is not confined by the Miocene marls (Figure 2). The Miocene aquifer connects to the Bou Regreg River and the dammed lake of Sidi Mohammed ben Abdellah. The larger farms and industries pump water from the Mamora aquifer, and some have deep wells to pump from the Miocene aquifer. The traditional, small farms take water from local groundwater bodies in the alluvial terraces. Depending on the recharge from precipitation, these bodies are incidentally connected to the Mamora aquifer.

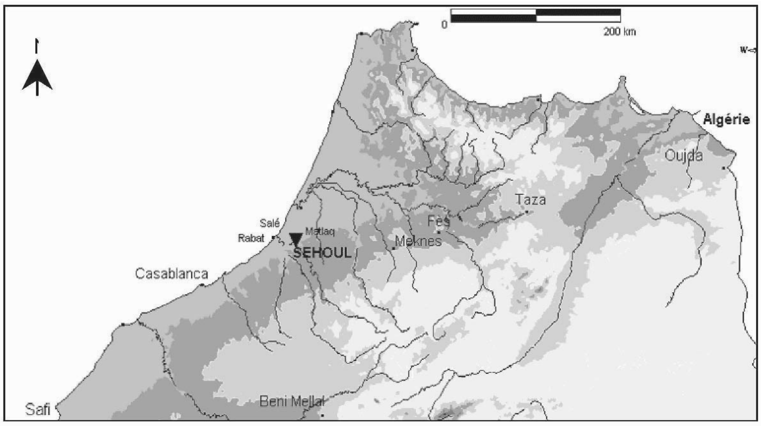

Figure 1. Location of the small agricultural catchment (Matlaq catchment) and the area considered for groundwater analysis (Sehoul region) in Morocco. The meteorological station of Rabat-Salé is located in Rabat

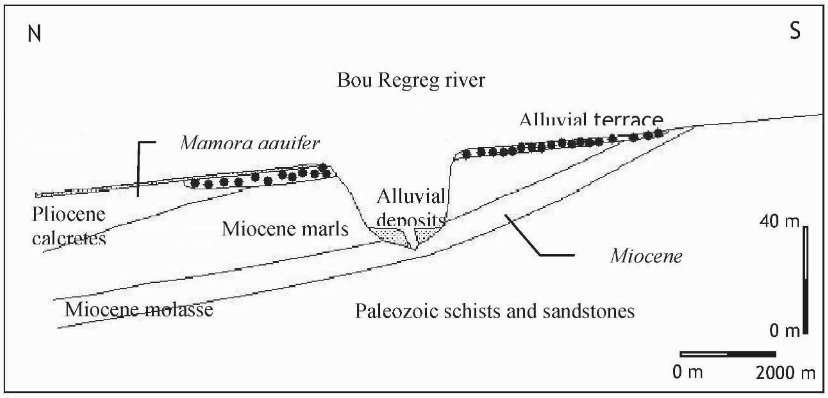

Figure 2. Geological cross-section through the Sehoul region and position of the groundwater systems (italic)

METHODS

Climate modelling

Current and future climate (1990 and 2050, respectively) for the Matlaq catchment were modelled by dynamical downscaling using the outputs of the MUGCM as initial and boundary conditions to the MM5 model (V3.4). The version of the MUGCM used is a spectral atmospheric model truncated at wave 31, which corresponds to a horizontal resolution of approximately 3.75°(longitude)*2.25°(latitude). The model uses nine vertical sigma levels. Both the diurnal and the seasonal cycle are included. Radiation is allowed to interact with CO_2, ozone, water vapour and clouds. The model includes prognostic clouds, sea-ice and prescribed sea surface temperatures (SST). In order to evaluate the statistical significance between the two climates, two 31-year long equilibrium simulations were performed with the MUGCM. The first climate represents the present climate and was forced with present CO_2 – equivalent greenhouse gas concentrations (control simulation – centered in 1990). The second climate represents a future climate centred in year 2050 and was forced by estimated CO_2 – equivalent greenhouse gas concentrations. Both simulations used climatological simulated SSTs as lower boundary conditions. These were provided for the respective period by the ocean-atmosphere coupled model of the Hadley Centre (HadCM2) (Mitchell and Johns, 1997). For the present-day simulation the CO_2 - equivalent greenhouse gas concentration was specified as 348 ppmv (from Atmospheric Models Intercomparison Project – AMIPII). The CO_2 concentration for the climate centered in 2050 was estimated according to the CO_2 forcing change between 2050 and the present day simulated by the HadCM2. This forcing change of 3 $W.m^{-2}$ resulted in an estimate of the CO_2 concentration of 634 ppmv. The CO_2 forcing in the MUGCM and HadCM2 models is similar.

MM5 is a powerful meteorological model that contains comprehensive descriptions of atmospheric motions: pressure, moisture, and temperature fields, momentum, moisture, and heat fluxes, turbulence, cloud formation, precipitation, and atmospheric radiative characteristics. MM5 is a nested-grid primitive-equation model which uses a terrain-following sigma (non-dimensionalized pressure) vertical coordinate. The outputs of the MUGCM model which were used as initial and boundary conditions for the MM5 model consisted of daily values of temperature, relative humidity, wind speed, wind direction, geo-potential height, sea level pressure and sea surface temperatures (SSTs). MM5 was applied to specific precipitation events selected among the MUGCM daily values of precipitation. From the MUGCM outputs of the 31 simulations for the 1990 and 2050 climates, precipitation episodes were selected having ≥5 mm/day during more than 2 consecutive days. The precipitation episodes were compared to observed episodes at the meteorological station of Rabat-Salé (MARS Crop Yield Forecasting, JRC). The length of the episodes simulated by the MUGCM model (3 days), the average precipitation in each episode (10-30 mm/day) and the occurrence of the episodes in the year (November, December, January) were in good agreement with the observed episodes at Rabat-Salé. Therefore, the results of the MUGCM model for Morocco were considered reliable for input into the MM5 model. For this purpose, the episodes were selected that represented the average duration and precipitation amount for the selection of episodes in the 1990 and 2050 climates (28 September-1 October 1990 and 26-29 October 2050). Episodes in autumn were chosen because the risk of land degradation due to surface runoff is highest in this season, when the soils are dried out after the summer, and rainfall intensities are highest.

Subsequently, the MM5 model was applied to downscale the selected precipitation episodes for the 1990 and 2050 climates to progressively smaller spatial domains with increasing spatial resolution and to higher temporal resolutions (Figure 3 and Table 1). For the application of the surface runoff and groundwater flow models, data at the level of domain D4 are required.

Seasonally averaged temperature outputs for domain D2 for 1990 were compared to observed climate data for the period 1960-1990 from the Climate Research Unit (New *et al*., 2002). The MM5 outputs were in good agreement with the observed data for Morocco over the period 1960-1990. The MM5 model was therefore considered suitable to simulate temperatures and precipitation representative for domain D4 for 1990 and 2050.

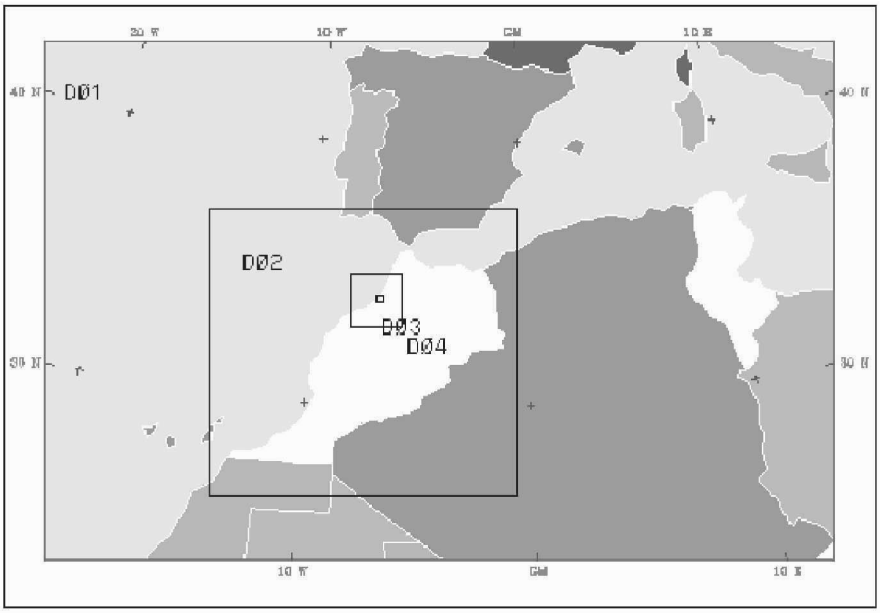

Figure 3. MM5 modelling domains

Table 1. Spatial domains of MM5

Domain	Geographical extent	Grid cells	Resolution (km)	Area (km^2)
D1	Western Mediterranean	41*63	54	2214*3402
D2	Morocco	67*73	18	1206*1314
D3	Rabat region	37*37	6	222*222
D4	Sehoul Plateau and Matlaq catchment	16*16	2	32*32

The MM5 outputs for the grid cell containing the Matlaq catchment were used for the surface runoff modelling. The temporal resolution of these outputs is 10 minutes. The groundwater flow model requires daily based weather data for the duration of at least a season. Due to computational constraints, MM5 could not be run for this temporal domain. Therefore historical meteorological data were used to run the groundwater flow model.

Surface runoff modelling

Surface runoff was modelled for the Matlaq catchment using the event-based Limburg Soil Erosion Model (LISEM) (Jetten, 2002). LISEM simulates surface runoff and erosion in small agricultural catchments for individual rain events. Surface runoff is considered the most important process for the transport of rainfall to the outlet of the catchment due to the susceptibility of the soils to sealing and the absence of root networks for sub-surface flow.

The event of 24-25 December 2001 was chosen as a representative autumn event for the climate centered around 1990. LISEM (version 2.10) was calibrated to this event for the Matlaq catchment using rainfall and runoff data measured with, respectively, a tipping bucket and V-nodge. The event brought 22 mm of rain in 24 hours, giving an abrupt runoff response at the outlet (within 5 minutes from the onset of rain), with 1140 m^3 of total runoff, a peak discharge of 467 l/s and a runoff coefficient of 7.6%. The runoff coefficient is defined here as the percentage of the total rainfall discharged from the catchment as overland flow and stream discharge (together termed ‘surface runoff’). The maximum rainfall intensity during the event was 48 mm/h.

LISEM works with maps of soil physical, soil surface and crop parameters. These maps were constructed by attributing parameter values to fields based on their land use and soil type. This was done under the assumption that more than one set of parameter values could reproduce the surface runoff variables and patterns observed during the calibration event of 24-25 December, following the principle of equifinality (Beven and Binley, 1992). Therefore multiple sets of parameter values were accepted as likely representations of the catchment. Parameter values for the combinations of soil type and land use type were measured in field campaigns in spring and autumn 2002. For each parameter, 100 maps were constructed by random selection from the uniform range of values available for the parameter.

LISEM was run for all 100 parameter sets, giving 100 sets of model outputs. The model outputs considered for each set included a hydrograph at the outlet at 10 minute temporal resolution, the total discharge at the outlet, the peak discharge, the time of peak discharge from the start of the rainfall event, and the runoff coefficient. From the 100 sets of model outputs, the 10 most 'likely' sets were selected by conditioning to the observed peak discharge and runoff coefficient using the GLUE methodology (Beven and Binley, 1992; Romanowicz *et al*., 1994) as implemented in the GLUEWIN software (version 1.0, 2001) (Ratto *et al*, 2001). The 2*10 sets of parameter maps corresponding to the 'most likely' model outputs were retained for the simulation of the rainfall scenario representative of the 2050 climate and a scenario in which the grazing area is reduced.

The 'reduced grazing area scenario' refers to the current transformation of collective grazing fields on the Sehoul Plateau into cultivated fields due to the construction of new farms with urban investment. The effects on surface runoff production of the transformation of ancient grazing fields into cultivated fields were evaluated in simulations in which grazing fields were attributed similar values of the infiltration capacity to cultivated fields for situations with tillage along and across the slope contour. The local drain direction map for the situation with tillage along the slope contour was created as a function of the direction of tillage and the direction of the steepest slope using the algorithms of Karssenberg (in Van Dijck, 2000). The simulations were run for the event of 24-25 December 2001.

Groundwater modelling

A 3-dimensional, numerical steady-state groundwater flow model was developed for the groundwater systems in the Sehoul Plateau within the MODFLOW code (PMWIN 5.1, McDonald and Harbaugh, 1988). Because of the inability of MODFLOW to handle perched water tables, and considering the importance of the uppermost groundwater system for the majority of farms in the area, groundwater flow was modelled only in the Mamora aquifer (Figure 2). The modelled system consisted of four layers, representing from top to bottom the Mamora aquifer, the Miocene marls, the Miocene molasse and the impermeable Paleozoic substrate. The geometry of the geological layers was derived from the geological map 1:100.000 (Fetah *et al*., 1989). Each layer was divided in 115*125 grid cells of 150*150 m^2. The GIS PCRaster (Wesseling *et al*., 1996; Burrough and McDonnell, 1998) was used for data input and visualization of output data.

The boundary condition imposed at the top of the modelled system was the soil surface elevation (DEM). The DEM was created by interpolation from 50 m contour lines from the 1:50.000 topographical map (DdlC, 1996a; DdlC, 1996b) using an iterative finite difference interpolation technique (Hutchinson, 1988; Hutchinson, 1989). The lower boundary of the modelled system (Paleozoic schists) was considered impermeable. A constant piezometric head was imposed to the northern border of the system, representing the lateral inflow of groundwater from the higher elevated Mamora Plateau, which borders the Sehoul Plateau to the north-west. Free outflow from the Mamora and Miocene aquifers was allowed along the western, southern and eastern boundaries of the area, in correspondence with the dip and encasement of the Sehoul Plateau. No inflow was allowed.

Initial conditions included the water levels in the Bou Regreg and Grou rivers and the dammed lake of Sidi Mohammed ben Abdellah. These levels were obtained from differential GPS measurements. The model runs at a daily timestep. Simulations were done for years representing the 1990 and 2050 climates, using meteorological data from the meteorological station of Rabat-Salé (MARS Crop Yield Forecasting System, JRC). For the 1990 climate, data were selected from the year with seasonal precipitation and seasonal daily temperature closest to the average seasonal precipitation and temperature over the period 1976-2002 (Table 2). For the 2050 climate, data were selected from the year with seasonal precipitation and daily temperature closest to the values predicted by the MUGCM for 2050 (Table 2).

Table 2 Precipitation (P) and temperature data (T) for meteorological years observed at Rabat-Salé representing the 1990 and 2050 climates. $\sum(\Delta P)$: summed deviations of seasonal precipitation from average seasonal precipitation in 1976-2002 or from MUGCM predictions for 2050; $\sum(\Delta T)$ idem for seasonal daily temperature

Climate and selection criterion (T or P)	**Year**	**$\sum(\Delta P)$ (mm/day)**	**$\sum(\Delta T)$ (ºC)**	**Annual P (mm)**	**Annual daily T (ºC)**
1990 (P)	1998	+0.26		323	
1990 (T)	1986		0.00		17.3
2050 (P)	1985	-0.08		234	
2050 (T)	1995		-2.67		18.6

Groundwater withdrawal was quantified using annually averaged abstraction rates from the artificial wells (0.5 m^3/day by hand power, 5 m^3/day by pumping) and the two public water supply points in the area ('chateaux d'eau', 7 and 17 m^3/day). Abstraction rates were determined from questionnaires among farmers in the study area.

Lateral outflow and percolation from the Mamora aquifer through the underlying Miocene marls are assumed negligible. Inflow to and drainage of surface water from the Sehoul Plateau is through the rivers Bou Regreg and Grou, which are represented in the modelled system, together with gullies functioning during heavy rainfall events.

The MODFLOW code does not simulate groundwater recharge by precipitation as a function of precipitation and evapotranspiration, but represents it as a net input flux in the model. In order to simulate the effects of changes in precipitation and evapotranspiration due to climate change, groundwater recharge by precipitation was simulated using the WOFOST crop growth model, version 7.1.2 (Boogaard *et al*., 1998). WOFOST estimates the growth of an annual crop, given a set of specific soil and weather conditions. Simulations were performed for rainfed grain maize and winter wheat, the most dominant crops in the cultivated area of the Sehoul Plateau. In the absence of data on cork oak, simulations could not be done for this type of vegetation. Crop growth was assumed to be water-limited.

In the absence of detailed crop data for the Sehoul region, data were used for grain maize and wheat varieties from Southern Italy, Greece and Southern Spain (Boons-Prins *et al.,* 1993). Based on the texture of the cultivated soils, soil data were taken from the EC2-medium group according to the soil map of the European Community (CEC, 1985; Reinds *et al*., 1992). Initial conditions of surface depression storage, initial water content in the actual root zone, and available water in the maximum rooting zone were obtained from field measurements of the surface roughness and soil moisture content in December 2002 and January 2003. The annual runoff coefficient was set to the values simulated with LISEM for the rainfall events representing the climate in 1990 (24-25 December 2001) and 2050 (26-29 October 2050).

WOFOST was calibrated for the year 2000 by tuning the emergence date and the rooting depth, and comparing the dry grain production of grain maize and winter wheat with observed harvest data for the Sehoul region (Chaker, pers. comm.). Next, WOFOST was applied to simulate groundwater recharge by precipitation for the years representing the 1990 and 2050 climates. The groundwater recharge rates were input to the groundwater flow model.

For the calibration of the groundwater flow model, piezometric levels of the Mamora aquifer were determined in 82 artificial wells between

31 August and 6 October 2003. The levels represent the lower state of the Mamora aquifer because they were taken at the end of the dry summer season. No rain fell during the observation period. Calibration was done by tuning the saturated hydraulic conductivity of the 4 geological layers and the lateral inflow from the Mamora Plateau at the northern border of the study area. The mean absolute error between observed and calibrated groundwater levels in the artificial wells was used as the objective function.

RESULTS

Climate modelling

Spatial averages of temperature and precipitation were computed from the MUGCM outputs for the Moroccan region (D2, Table 1 and Figure 3), on a seasonal basis. A two-tailed t-test was used to estimate the statistical significance of the differences between the 1990 and 2050 climates (ensemble means and variability).

The climate in Morocco in 2050 will be 2.4 K warmer in winter, spring and summer, and 1.7 K warmer in autumn compared to the 1990 climate. Precipitation will decrease in all seasons, but most significantly in spring and summer, by respectively 0.2 and 0.3 mm/day (Figure 4). The variability of spring precipitation decreases significantly in the 2050 climate compared to the 1990 climate, while the variability in autumn precipitation increases.

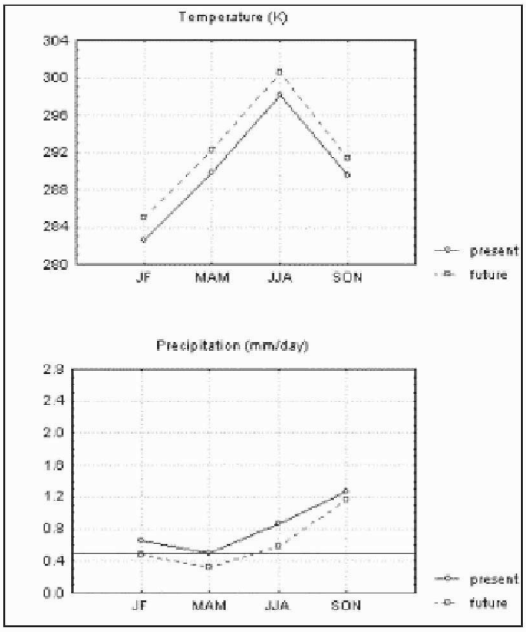

Figure 4. Seasonal means (MUGCM outputs) of temperature and precipitation for the Moroccan region. Present: climate centered in 1990; future: climate centered in 2050

According to the simulations by MM5, the seasonal average daily temperatures over the Moroccan region (domain D2) increase from 1990 to 2050 in all seasons. Averaged over the domain, the minimum value of the daily temperature will increase most in winter (+3.1ºC), the maximum most in spring (+2.7ºC) (Figure 5).

The precipitation episode selected for simulation with the MM5 model for the 1990 climate provided no precipitation in the Matlaq catchment. Therefore a historical rainfall event was used, representative of autumn conditions in the climate centred around 1990. The characteristics of the rainfall events representative of the climates centered around 1990 and 2050 are given in Table 3. The events are of comparable duration, but the event representative of the climate centered around 2050 has a larger total rainfall amount, a higher maximum rainfall intensity and a shorter total of dry periods during the event. The larger total rainfall amount and maximum rainfall intensity reflect the larger variability in autumn precipitation predicted by the MUGCM. The time series of precipitation intensity were input to the LISEM model.

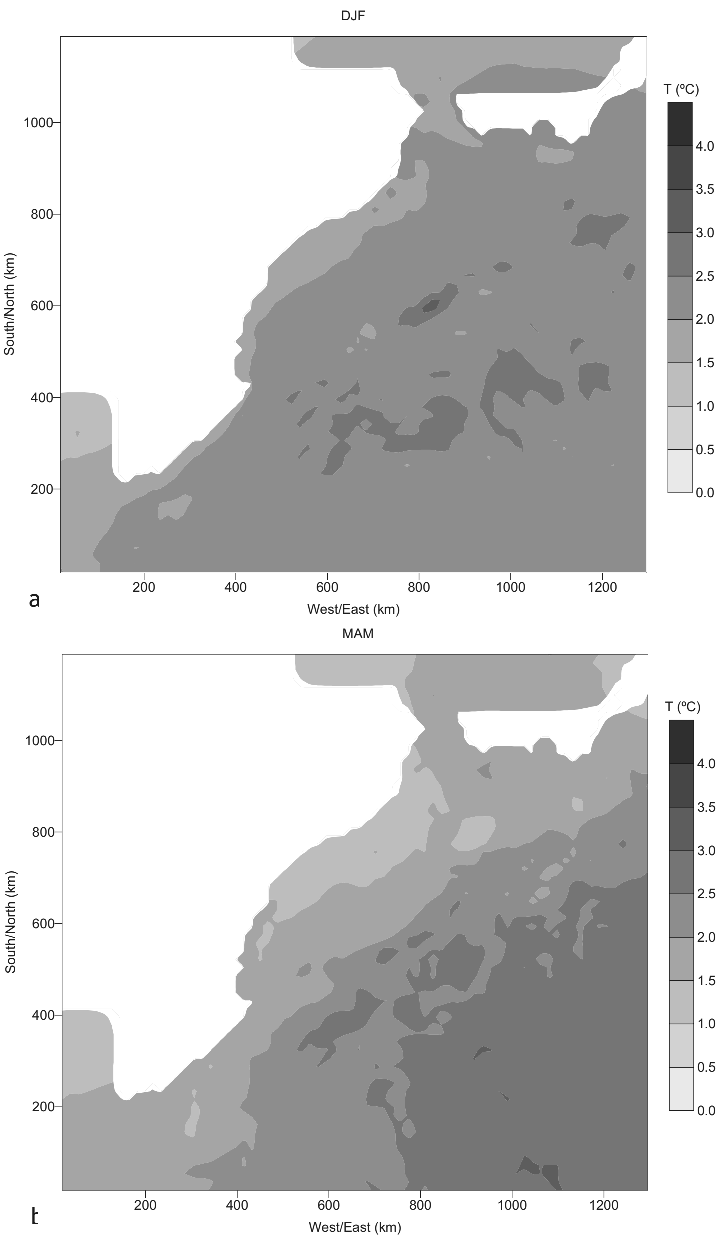

Figure 5. Differences between average daily temperature in the 1990 and 2050 climates simulated by MM5 over the Moroccan region for winter (a) and spring (b)

Table 3. Characteristics of rainfall events representative of climates centered around 1990 and 2050

Characteristic	24-25 Dec 2001	26-29 Oct 2050
Total rainfall (mm)	22	64
Maximum rainfall intensity (mm/h)	48	66
Duration (h)	30.3	28.8
Dry periods (% of duration)	87	73

Surface runoff modelling

Calibration

The results from the 100 LISEM simulations for the calibration event of 24-25 December indicate that the total discharge and the runoff coefficient are underestimated in most model runs, whereas the time to peak runoff is overestimated by 5 to 15 minutes. These deviations may be explained by sealing of the soil surface, a process not simulated by LISEM. The silt, silt loam and silty clay soils in the catchment are sensitive to sealing (Nafaa, 2002). Despite the general underestimation of the total discharge and runoff coefficient, the observed values of these outputs are within the 90% confidence bounds of the model results (respectively 730 and 1263 m^3 and 4.9-8.5%). In the selection of the 10 most likely model runs conditioned to the observed runoff coefficient, the confidence bounds are narrowed to 6.1-7.7% for the runoff coefficient.

The observed peak discharge is close to the average simulated peak discharge, and well captured by the simulated values in the 100 model runs. Yet, the 10 most likely model runs conditioned to the runoff coefficient have peak discharges well above the observed peak discharge (743-1046 l/s versus 467 l/s). This is probably because in none of the model runs the progressive decline of the observed hydrograph is simulated (Figure 6). The runoff volume discharged during recession (1120-1410 minutes) amounts to 540 m^3, almost half of the total observed runoff. The extra discharge required to comply with the observed runoff coefficient is obtained from a higher simulated peak discharge. A progressive decline of an observed hydrograph is often attributed to delayed throughflow reaching the channel after the overland flow from the hill slopes (Ward & Robinson, 1991; Brooks *et al*., 1997), but it is also observed in agricultural catchments not manifesting throughflow (e.g. Van Dijck, 2000; Van Asch *et al*., 2001).

Delayed throughflow may come from the gravely alluvial deposits and the fissured clays adjoining the downstream part of the channel. In addition, the long tail of the observed hydrograph may be explained by the inability of LISEM to simulate infiltration in the channel bed.

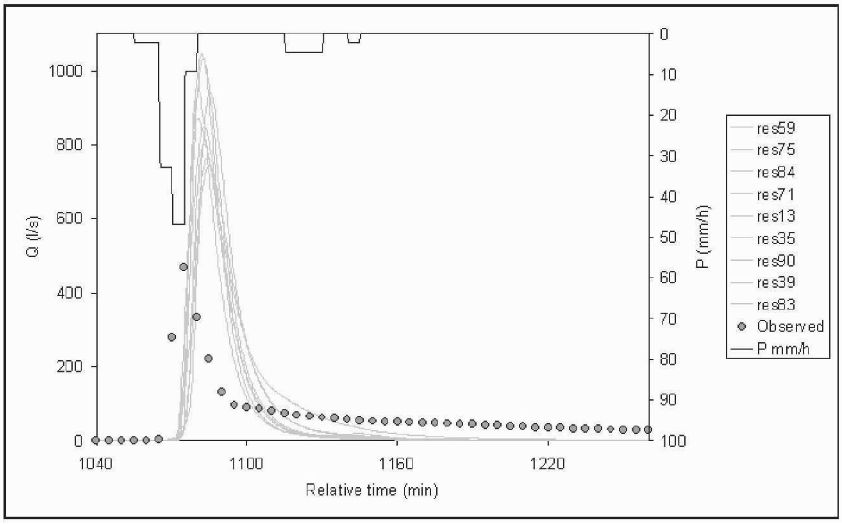

Figure 6. Observed discharge at the outlet of the Matlaq catchment during the event of 24-25 December 2001 and discharge simulated in the 10 most likely model runs conditioned to the runoff coefficient

With regard to the spatial patterns of surface runoff, all likely model runs have in common that surface runoff is simulated in fields under grazing since long, or fallow fields on soils developed in hillslope deposits or in ancient alluvial terraces on the upper slopes. The surface runoff production on these fields is the result of several factors, represented in the parameter values of the model runs selected to most likely represent the catchment behaviour: 1. the low infiltration capacity of the silty clay soils, aggravated by sealing and compaction by cattle. This influence is reflected in small values of the saturated hydraulic conductivity (< 1 mm/h); 2. the limited soil moisture storage capacity due to the limited soil depth (40 cm for soils on the eroded south-east oriented hillslope) or due to an impeding horizon (petro-calcic horizon or Bt-horizon in the fersiallitic soils); 3. the small vegetation cover of the fallow and grazing fields concerned, reflected in small values of the leaf area index, and 4. the small suction at the wetting front (5-30 cm). This may be due to the attenuating effect on the hydraulic gradient in the soil by the limited soil depth or an impeding horizon.

Phenomena of soil erosion were observed in the field at the places where surface runoff was simulated (denudated soils, rills) (e.g. Figure 7). This supports the likeliness of the catchment representation in the selected parameter sets.

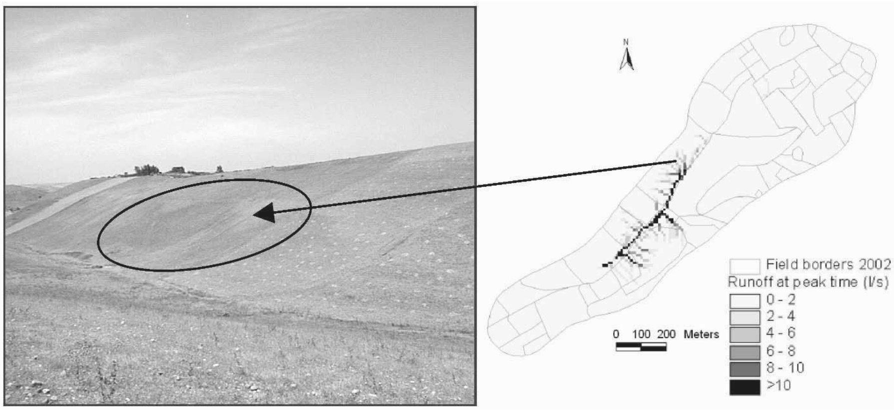

Figure 7. Traces of regular sheet and rill erosion on the south-east oriented slope of the Matlaq catchment, and surface runoff map at peak time simulated by LISEM (l/s)

Reduced grazing area scenario

Considerably less runoff was produced at the catchment outlet when the infiltration capacity in ancient grazing fields is set to values typical of cultivated fields (Figure 8), even when tillage is in the direction of the steepest slope. The total discharge and peak discharge were reduced by respectively 58-84% and 47-84%. The runoff coefficient was reduced by 58-84%. As expected, the total infiltration increases (by 5-7%). The peak time does not change as a result of the changed infiltration capacity. This is probably because the initial suction at the wetting front, which determines the decrease of the infiltration rate at the beginning of a rainfall event, was not changed for the grazing fields.

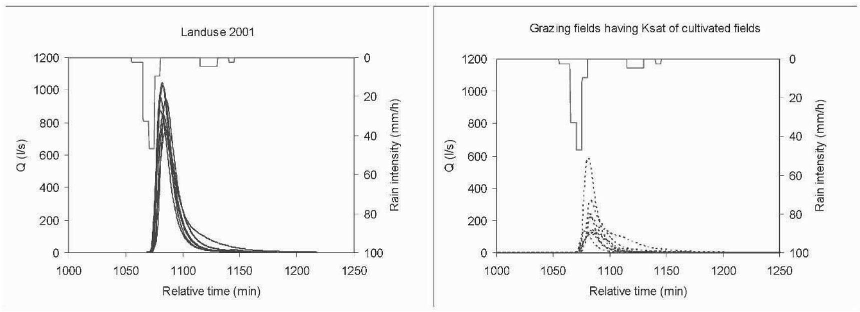

Figure 8. Discharge at the outlet of the Matlaq catchment under land use distribution of 2001 and with infiltration capacities (Ksat) of ancient grazing fields set to values of cultivated fields – event 24-25 December 2001

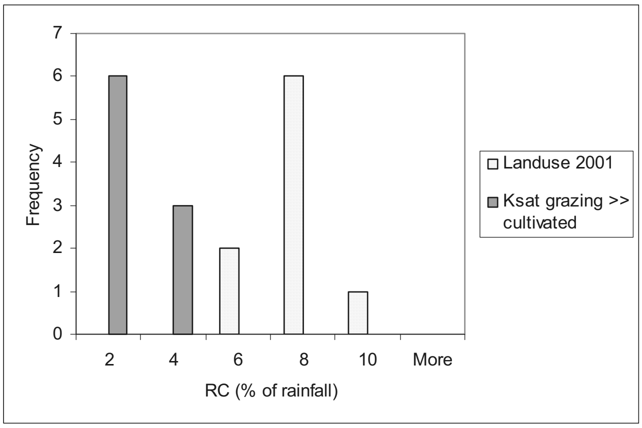

Figure 9. Runoff coefficient of Matlaq catchment under land use distribution of 2001 and with infiltration capacities (Ksat) of grazing fields set to values of cultivated fields – event 24-25 December 2001. Frequency: number of model runs

With tillage along the slope contour on the forming grazing fields, the direction of the surface runoff is changed to the direction of tillage. For sheet flow, this results in slowing down of the surface runoff due to the reduced bed slope angle and a larger flow depth, enhancing re-infiltration. If the surface runoff concentrates in tillage furrows, the reduction of the flow velocity may be compensated by the larger value of the hydraulic radius (Van Dijck, 2000). Because sheet flow was simulated, less surface runoff was expected to come from the concerned fields and at a slower rate. This was confirmed by the smaller peak discharge (6-25%) and total discharge (3-10%) at the catchment outlet compared to the hydrographs for the situation with tillage in the direction of the steepest slope (Figure 10a) The timing of the discharge at the catchment outlet is not influenced by the change of tillage direction (Figure 10). This can be explained by the larger influence of the channel network on the hydrograph at the catchment outlet compared to the fields on the hillslope due to larger flow distances and velocities in the channel network.

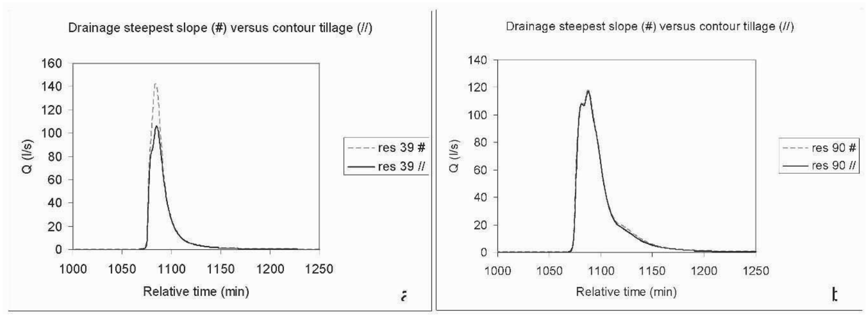

Figure 10. Discharge at the outlet of the Matlaq catchment for tillage across (#) and along the slope contour (//) on former ancient grazing fields for model runs 39 and 90.

Climate change scenario

The peak discharges and runoff coefficient are considerably larger for the event representing the climate of 2050 (resp. 2582-3659 l/s and 17-27%) than for the event representing the climate of 1990 (743-1046 l/s and 6-9%) (Figure 11, Figure 12). This is due to the larger total rainfall amount of the event in 2050, but more so due to the larger maximum rainfall intensity. Runoff is generated in the Matlaq catchment due to sealing of the soil surface rather than by filling up of the soil moisture storage capacity. Therefore the rainfall intensity has a stronger influence on the peak discharge and the runoff coefficient than the total rainfall amount.

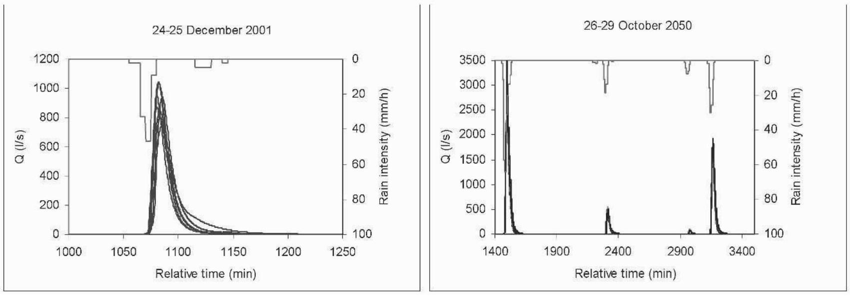

Figure 11. Hydrographs at outlet of Matlaq catchment for the 10 most likely model runs for the rainfall events representing the climates in 1990 (24-25 December 2001) and 2050

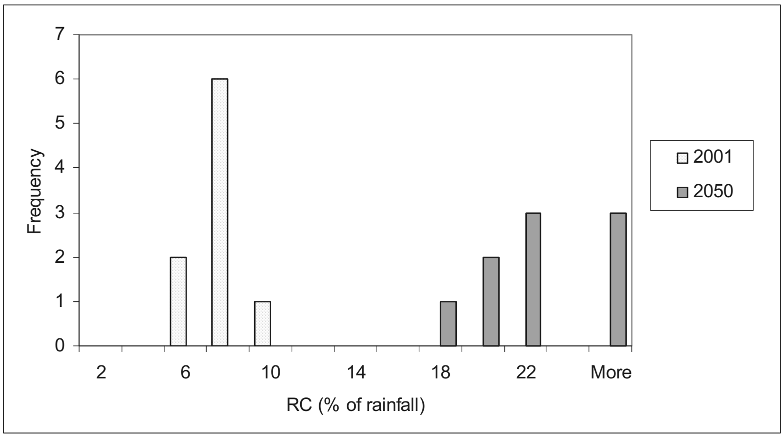

Figure 12. Runoff coefficient of Matlaq catchment for the rainfall events representing the climates in 1990 (2001) and 2050. Frequency: number of model runs

Groundwater modelling

Calibration

The differences between observed and calibrated groundwater levels in the artificial wells are large, ranging from -20 to +20 m near the Bou Regreg and Grou Rivers with extremes up to +70 m east of the dammed lake of Sidi Mohammed ben Abdellah. Differences are between 0 and -30 m in the higher parts of the area away from the rivers. The mean absolute error for all the wells is 18 m.

The poor calibration results may be explained by: 1. insufficient knowledge of the subterranean structure, hydraulic conductivity and initial hydraulic heads of the four geological layers, 2. incorrect lateral boundary conditions, 3. the absence of seasonality in the groundwater recharge by precipitation, 4. the spatial variability of surface elevation and measured groundwater levels and 5. The homogeneous land use assumed over the study area. The observed groundwater levels refer to the levels measured in artificial wells, whereas the calibrated levels should represent the average groundwater level over a cell of 150*150 m^2. The surface elevation and well level may vary by up to respectively 50 and 25 m over a distance of 150 m. The land use influences the groundwater recharge by precipitation by determining water uptake by natural vegetation and crops and evapotranspiration. For the calculation of groundwater recharge from precipitation with WOFOST, homogeneous land use consisting of winter wheat in rotation with grain maize was assumed, whereas 22% of the study area consists of cork oak forest. This type of forest is known to exert influence on groundwater levels in the Mamora aquifer due to its large water uptake (Chaker, pers. comm.).

Groundwater recharge

The annual groundwater recharge by precipitation simulated by WOFOST for the historical years representing the 1990 and 2050 climates is given in Table 4. A general decrease of the annual groundwater recharge from the climate in 1990 to the climate in 2050 appears for the years representative of these climates with respect to both seasonal precipitation (40%) and temperature (68%).

The simulation of groundwater levels for 1998 failed because the groundwater flow model became instable. The difference between groundwater levels simulated for 1986 and 1995 are shown in Figure 13. In the major part of the area, the difference is between 0 and -5 m. Positive differences occur along the northern border of the study area. These may be caused by the larger effect of the positive hydraulic head imposed along this border under the smaller annual groundwater recharge in the 1995 scenario. Cells with differences up to +50 m and down to -50 m occur in cells scattered along the Bou Regreg river and in the central part of the Sehoul Plateau. These extreme differences are caused by instability of the groundwater model at cells drained below a certain threshold groundwater level in either the 1986 or 1995 scenarios.

Table 4 Annual groundwater recharge (AGR) simulated by WOFOST using meteorological data from 4 historical years at Rabat-Salé representing the 1990 and 2050 climates. T: seasonally averaged daily temperature; P: seasonal precipitation

Climate and selection criterion (T or P)	**Historical year**	**AGR (mm)**	**Climate and selection criterion (T or P)**	**Historical year**	**AGR (mm)**
1990 (P)	1998	134	2050 (P)	1985	80
1990 (T)	1986	244	2050 (T)	1995	167

DISCUSSION AND CONCLUSIONS

The MUGCM and MM5 simulations indicate an increase of seasonal temperature and a decrease of seasonal rainfall in Morocco between the climates centered in 1990 and in 2050. The general trend of these findings are in correspondence with the annual projections for Morocco over the period 2000-2020 by the UN Convention on Climate Change in 2001 (0.6-1.1 °C), but the temperature increase indicated by the MUGCM and MM5 simulations (1.7-3.1 °C on a seasonal base) is larger. The difference may come from the longer time frame considered in the MUGCM and MM5 simulations, but also from differing methods used to estimate future temperature. The decrease in rainfall simulated by MUGCM (0.02-0.3 mm/day on a seasonal base) corresponds with the prospect of the UN Convention on Climate Change (0.3 mm/day).

The increase of the variability of rainfall in autumn indicated by the MUGCM simulations has implications for groundwater recharge, crop production and land degradation. In autumn with a few heavy rain storms, a large part of the rainfall may be lost as surface runoff, entraining soil, seeds or emergent crops from freshly ploughed and sown fields and cause downstream siltation. This is expressed in the results of the event-based surface runoff simulation for the 2050 climate, giving considerably higher values of the peak discharge and the runoff coefficient compared to the simulation for the 1990 climate.

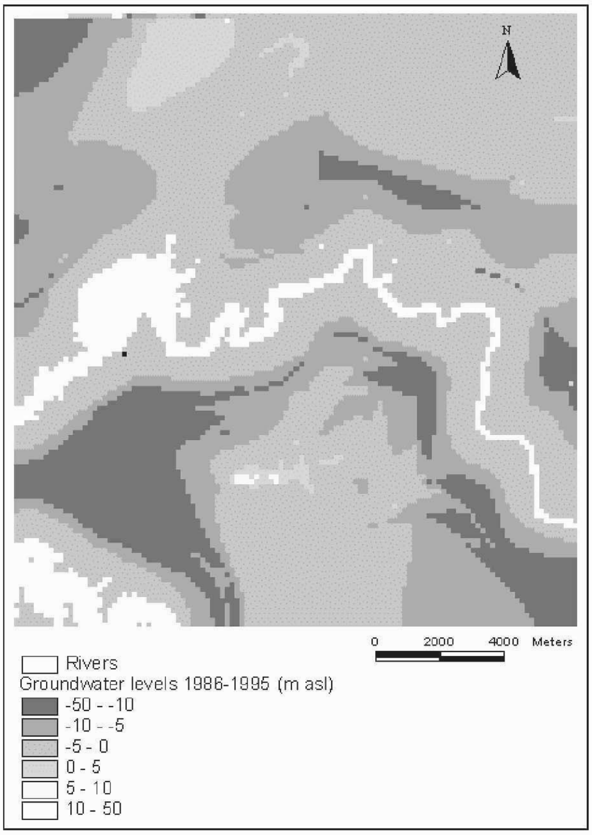

Figure 13. Simulated groundwater levels in 1990 (simulated year 1986) minus groundwater levels in 2050 (simulated year 1995)

The results of the surface modelling with LISEM show that surface runoff – but not necessarily soil erosion - is mainly produced in ancient grazing fields and fallow fields. Fallow fields are less susceptible to runoff production when left with an important vegetation cover in winter and spring and with crop remnants in autumn, implying a reduced grazing pressure. In a comparison of runoff intensity on fields with different land use and management, Laouina *et al*. (2000) showed that runoff production is highest on ancient grazing fields which have experienced soil degradation in the past due to over-use in cultivation. Recently tilled fields are in the second place due to destruction of the soil structure, crusting and rill formation. However, despite the smaller volumes of surface runoff produced, recently tilled fields record much more erosion than ancient grazing grounds, especially under autumn rain storms (Laouina *et al*., 2000). This is explained by the concentration of surface runoff in the furrows of tilled fields and the formation of rills, especially when tillage is in the direction of the slope. The surface runoff from the grazing fields is less concentrated and can even benefit crop growth and groundwater recharge by re-infiltration in downslope areas. If the sediment load of the runoff is small, the runoff can benefit the refilling of dam reservoirs, which are the main source of irrigation and water supply for cities.

The surface runoff simulations confirm that less runoff is produced on cultivated fields compared to grazing fields, even when tillage is in the direction of the steepest slope. However, the simulations do not indicate the type of surface runoff occurring, neither the associated soil erosion. Changing the tillage direction to that of the slope contour on cultivated fields reduces the total and peak discharge at the catchment outlet, but only when the surface runoff is not allowed to concentrate in tillage furrows. This condition occurs when the soil surface is leveled after tillage.

The study of Laouina *et al*. (2000) showed that less runoff is produced on fields tilled and planted with cereals early in the autumn season and fields recently lain in fallow, not tilled in autumn and left with crop remnants. In view of the current transformation of collective grazing fields into cultivated land, problems with loss of rainfall in surface runoff and soil erosion could be mitigated by 1. early tillage of cultivated fields along the slope contour, followed by leveling, 2. locating cultivated fields downslope of grazing fields to enable the capturing of diffuse surface runoff coming from the grazing fields, and 3. leaving fallow fields untilled and covered with crop remnants.

The results of the WOFOST crop growth model indicate a decrease of the annual groundwater recharge by rainfall of 40-68% from the climate centered in 1990 to the climate centered in 2050. These results are based on the increase of temperature and decrease of rainfall simulated by the MUGCM, and on the increase of event-based runoff coefficients simulated for autumn conditions by LISEM. Because the highest event-based runoff coefficients are recorded in the study area in autumn, the annual groundwater recharge is underestimated for both climates. Other uncertainties in the simulated decrease of the annual groundwater recharge include the representativeness of the selected historical meteorological years for the climates centered in 1990 and 2050 apart from the similarity of seasonal rainfall or temperature, and the applicability of the calibration settings of the WOFOST model (for the year 2000) to the climate centered in 2050.

Based on the simulated annual groundwater recharge, the groundwater flow model predicted a fall of groundwater levels between 0 and 5 m in the major part of the Sehoul Plateau. This decrease is much smaller than the mean absolute calibration error of the groundwater flow model (18 m), and therefore the results cannot be considered reliable. In addition, the decrease is similar to the range of intra-annual fluctuations of the Mamora aquifer in the Sehoul Plateau (ca 3 m, Direction Générale de l'Hydraulique, 2004). In the south-western part of the Mamora Plateau, which borders the Sehoul Plateau to the north, groundwater levels decreased with 7 m on average between 1963 and 1993 (Rapp. Onep/Gtz, 1994). This decrease is mainly attributed to population growth and the expansion of the cultivated area in this region (Nafaa, 2002). The added effect of the climate change predicted in the present study may well be expected to cause an even larger decrease of groundwater levels in the Sehoul Plateau up till 2050, with a continuing desertification lying ahead.

ACKNOWLEDGEMENTS

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HYDROLOGICAL APPROACH FOR ASSESSING DESERTIFICATION PROCESSES IN THE MEDITERRANEAN REGION

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ABSTRACT

Land degradation, which affects the conservation of soil and water in adequate places, amounts and qualities, is the main direct cause of desertification. It is related to climate and soil characteristics, but mainly to deforestation and inappropriate use and management of natural resources including soil and water. The main effects are a decrease in water supply, a non sustainable agricultural and food production, and increased risks of catastrophic flooding, sedimentation, landslides, etc. In the medium or long term, the previewed global climatic changes may contribute to accelerate the processes of desertification in the Mediterranean Region, but in the short term, land use practices leading to soil degradation processes would increase the negative influence of those changes.

The processes of soil and water degradation, leading to desertification, are strongly linked to unfavourable changes in the hydrological processes responsible for the soil water balance and for the soil moisture regime. These are affected by the climate conditions and variations, and by the changes in the use and management of soil and water resources.

In the arid and semiarid Mediterranean climates, the rainfall is highly variable among years and during the year, and usually occurs in erratic storms of short duration and high intensities. This factor increases the risks of land degradation leading to desertification processes. In N

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Mediterranean countries, agricultural production patterns and practices have been drastically changed in the last decades, emphasizing labour-substituting technologies in some cases, with abandon of traditional soil and water conservation practices, and leading to the abandonment of agricultural lands in others. By contrast, in most of the S Mediterranean countries, population growth and lack of resources have obliged to intensify the use of marginal lands without appropriate conservation practices. Both situations frequently lead to accelerated land degradation and desertification processes, although in N Mediterranean countries, if resources are available, these processes and effects are usually masked by technological external inputs of energy, irrigation water, nutrients, and other control measures. Any break in these artificial measures, generally causes a complete loss of productivity and leads to accelerated desertification processes.

Hydrological approaches would be essential to identify and assess the causes and processes of desertification. The evaluation of the hydrological processes, under different scenarios of changing climate, soil properties, and land use and management, with flexible simulation models based on those processes, may help to predict and to identify the biophysical causes of desertification at local, national and regional levels. This is a required previous step for a rational land use planning, and for the selection and development of short and long term strategies and technologies to reduce or to control land degradation processes leading to desertification, and to the related social economic and security problems. There is proposed an integrated framework for the development of this kind of approach, with potential application under Mediterranean conditions.

INTRODUCTION

Soil performs a number of key environmental, social and economic functions vital for life. Agriculture and forestry are dependent on soil for the supply of water and nutrients, and for root fixation. Soils perform functions of storage, filtering, buffering and transformations, playing a central role in water protection and regulation, and on the exchange of gases with the atmosphere. Land degradation is a reduction in the soils capacity to produce sustainable, in terms of quantity and quality, goods (plants and food) and services (regulation of water; environmental filter). The result is a reduction or loss of the biological and economic productivity and complexity of the land.

Desertification is generally viewed as an advanced stage of land degradation, when vegetation cover falls below some level (about 35 %). For many people, desertification is the diminution or destruction of the biological potential of the land, that can lead ultimately to desert-like conditions, usually in dry lands, but sometimes even in humid ones. It is an oversimplified concept with a connotation of emotive image, addressed to decision makers as a way to attract attention, and it is hoped funds (CIESIN, 2003). Frequently there is an insidious misuse of the term *desertification* to deflect attention from more sensitive political and social problems, blaming the environment when blame should go to human institutions or individuals. As a consequence, the concept of desertification is still obscure, and therefore there is a lack of consensus on the nature and causes of desertification processes.

Rozanov (1982) proposed the following definition:

> "Desertification is a process of irreversible change, requiring a very long natural process for the restoration of the initial stage, of soil and vegetation of dry lands in the direction of aridisation and diminution of biological productivity, which, in extreme cases may lead to the total destruction of the biological potential and to the conversion of lands into desert."

According to Dregne (1983), desertification processes in arid and semiarid lands are:

- Deterioration of vegetative cover due to overgrazing and deforestation.
- Water and wind erosion resulting from improper land management.
- Salinisation and sodification due to improper use and management of irrigation water and drainage.

These processes reduce productivity rather than create total deserts, except in extreme cases.

Agenda 21 and the UNCCD (UNEP, 1997) consider desertification as the degradation of land in arid, semiarid and sub-humid dry areas, caused by various biophysical and human factors. The areas subject to desertification are defined by the ratio of precipitation (P) to potential evapo-transpiration (PET):

- Arid ($0{,}05 < P/PET \leq 0{,}2$).

- Semiarid (0,2 < P/PET ≤ 0,5).
- Sub-humid Dry (0,5 < P/PET ≤ 0,65).

Desertification is accompanied not only by a reduction in land and soil potential, but also by a decrease in surface and ground water resources, having negative repercussions on the living conditions and the economic development of the people affected by it. The main direct visible impacts of desertification are damages to crops, livestock, power generation, etc, with indirect effects on non-sufficient food production, poverty and social disruption, causing migration of people from rural areas to urban centres, or to other regions or countries, trying to improve their living conditions (FAO, 1993). Therefore, desertification may be better defined as a phenomenon derived from climatological, hydrological and socio-economic processes, leading to potential threats to the environment, with negative consequences on human welfare and lives.

In the past decades, the degradation of previously naturally vegetated or productive agricultural lands, leading in many cases to barren, desertified, landscapes, has dramatically extended in many regions of the World. The reasons are mainly unfavourable biophysical conditions and negative human impacts. The areas prone to degradation and desertification are often characterized by marginal soils, and low and highly variable rainfall. The negative human impacts are mainly through inadequate land use, including deforestation, overgrazing, and deficient agricultural practices, leading to soil erosion, salinisation and vegetation degradation, as a consequence of drastic changes in the water balance. This might be further aggravated by the ongoing threat of climate change.

Many of the programs to combat desertification have often concentrated up to now on mitigating the effects rather than fighting the causes. Instead, a program to combat desertification would require (Balba, 1982) a survey of the soil and water resources, followed by an identification of the problems and processes of land degradation, as a basis for the formulation of a plan of action to counteract such processes. A sufficiently precise assessment of the desertification processes must be based on the integration of biophysical and social economic factors, for diagnostic purposes and for guiding the implementation of sustainable land use and management strategies and programs (Pla, 1996, 2001).

Although legal measures are necessary for the rational use, management and conservation of the soil and water resources, they alone may not be sufficient for an adequate planning for the rational development of land resources. Soil and water conservation legislation has to be viewed within the larger context of land use planning, which requires site specific data on the physical and hydrological environment under actual or projected conditions. This generally requires improvements in the present research and inventories of soil and water resources, and in the training and formation of manpower at all levels.

DESERTIFICATION IN THE MEDITERRANEAN REGION

Desertification in the more vulnerable areas with arid and semiarid climate in the Mediterranean region goes back over millennia (Dupre, 1990). The most important human actions that have triggered or intensified the processes of land degradation have been overgrazing, deforestation and forest fires, and in recent decades new land management practices, associated to agricultural intensification, mechanization, inadequate maintenance or abandonment of vast areas of terraced agriculture, over-drafting of surface and groundwater for irrigated agriculture, tourism, etc. (EC, 2003). These new land use and management practices are a consequence of changes in social economic conditions, market prices and public policy-led subsidies, consumption patterns, etc, associated to technological progress and changing production systems. Desertification has affected more hilly sloping lands, but in valley bottoms where irrigation is being used for increasing productivity, salinisation and sodification have become a widespread form of soil degradation and desertification. There are evidences that land degradation processes leading to desertification in the Mediterranean region are getting worse, because of different or mixed causes varying from one place to the other (EC, 2003).

In N Mediterranean countries, agricultural production patterns and practices have been drastically changed in the last decades, emphasizing labour-substituting technologies in some cases, with abandon of traditional soil and water conservation practices, and leading to the abandonment of agricultural lands in others. By contrast, in most of the S and W Mediterranean countries, population growth and lack of resources have obliged to intensify the use of marginal lands, without appropriate conservation practices. The potential for desertification is still further enhanced through the direct effects of climate change on erosion, salinisation and fire hazard. In general, the most serious impacts on land degradation and desertification have been in the S Mediterranean countries, where lands are more under pressure due to social economic factors, including population growth.

Degradation of local land resources encourages out-migration to urban developed areas in the same country or to other neighbour countries, leaving fewer people to use and maintain local soil and water resources (EC, 2003). This underutilization and abandonment of already severely degraded land usually leads, mainly under arid and semiarid climates, to further degradation. But at times, depending on the soil water regime (soil and climate), population decline and decrease or absence of land use allows recovery and gradual restoration and improvement of soil and water resources. In N Mediterranean European countries, modern technologies, including intensive mechanization, for most of the land use operations, have been spreading fast in most of the dry-lands, for improving productivity and due to the affluence of rural population, with economic considerations often overriding environmental considerations.

Areas under desertification in the Mediterranean region include Central and SE Spain, Central and S Italy, S France, S Portugal, and extensive areas of Greece and N Africa. In poorer countries, especially in N Africa, desertification has more serious social economic consequences, and can ultimately cause the desestabilization of societies, triggering the migration of human populations. In richer European countries in the N of the region, trained human and capital resources are generally available for restoring partially degraded lands, and for masking processes and effects of land degradation and desertification, through technological external inputs of energy, irrigation water, nutrients, and other control measures. Any break in these artificial measures, generally causes a complete loss of productivity and leads to accelerated desertification processes.

Sustainable development in the Mediterranean region requires policies for the development of a long term approach of soil protection, based on an adequate knowledge of the potential direct and indirect impacts of human activities and climate changes, in order to select and apply the best practices and measures for conservation of the soil and water resources.

LAND DEGRADATION AND DESERTIFICATION. CAUSES AND EFFECTS

The formulation of a sound soils policy, and the prevention and choice of solutions for the problems of land degradation leading to desertification must depend on the right identification of the processes involved and in the precise analysis, diagnosis and understanding of the causes and potential effects at specific places. Not doing so may lead to catastrophic effects. Despite the modernization of observation facilities by the use of satellite imagery and computer programs to analyse the data, there are still many uncertainties at the regional and national levels in the Mediterranean region, on the causes, the extent and the seriousness of land desertification. These uncertainties prevent those who manage land resources from planning properly, and introduce constraints in operation of early warning systems with regard to agricultural production and disasters such as flooding and landslides.

Land degradation, which affects the conservation of soil and water in adequate places, amounts and qualities, is the main direct cause of desertification. It is related to climate and soil characteristics, but mainly to deforestation and inappropriate use and management of the natural resources soil and water. In degraded lands usually less water can infiltrate, and more rainwater will become surface runoff. The main effects are a decrease in water supply, a non sustainable agricultural and food production, and increased risks of catastrophic flooding, sedimentation, landslides, etc. resulting in destroyed crops, lands, infrastructures and buildings, and in killing people and animals. Sediment will be deposited in reservoirs, lakes and streams, which lead to reduced storage capacity, and reduced power output in power generation plants. Land degradation is together a cause and an effect of food security.

The causes of land degradation and desertification in the Mediterranean region are mainly related to complex interactions of diverse natural biophysical factors (climate, soil, topography, vegetation cover), which mainly determine the land hydrology, and social economic factors (population increase or decrease, migration, socio-cultural and economic changes, institutions), which determine land use changes (deforestation, fires, cropping, grazing, constructions) mainly affecting the hydrology of a territory. The ignorance of land users, and more of land planners and technical advisers about these changes in land hydrology related to changes in land use and management have a strong influence in the desertification processes in many cases.

In the medium or long term, it is previewed that global climate changes may contribute to accelerate the processes of desertification in the Mediterranean region (Imeson and Emmer, 1992), but at short term, land use practices leading to soil degradation processes would increase the negative influence of those changes. There are significant uncertainties in predictions of regional climatic changes, but probably the Mediterranean region will warm significantly, with more precipitation in winter and less in summer, and declining annual precipitation in the southern part (N Africa and SE Spain), increasing the frequency and severity of droughts, and the occurrence of extreme events. This will mainly affect the land hydrology (Wigley, 1992; Palutikof and Wigley, 1996).

Increasing frequency of droughts, based upon reduction in annual rainfall, leads to land desertification, but widespread incidence of drought could be a result of changing land use, without a necessary change in climate, through a reduction in the effectiveness of rainfall by land degradation processes. Climate variability changes in the frequency and magnitude of extreme events could have a greater impact than changes in mean climate alone. In mountainous areas of the Mediterranean region, with already degraded lands, heavy seasonal rainfall and extreme events may result in concentrated runoff, rushing down in great volumes as flash floods, causing extreme damage downstream. Landslides may also be initiated by those intense rainstorms in mountain areas.

Although economic forces, closely linked to political ones, drive people to degrade land, once this is overcome there is required to know how to manage the land to avoid such degradation, or to rehabilitate already degraded land. The basic causes of land degradation and desertification in the Mediterranean region are the same, but the prevention and remedial measures have to be adapted to local biophysical, social economic and political conditions.

HYDROLOGY AND DESERTIFICATION

Water, that is often the main limiting factor of plant growth, is also the main factor directly or indirectly responsible for soil and land degradation processes. These processes, leading to desertification, are strongly linked to unfavourable changes in the hydrological processes responsible for the soil water balance and for the soil moisture regime, which are affected by the climate conditions and variations, and by the changes in the use and management of soil and water resources.

The soil moisture regime, determined by the changes in soil water content with time, is the main single factor conditioning moisture availability, plant growth and crop production. It is mainly conditioned by soil properties affecting the capacity and possibilities of infiltration, retention and drainage of rainwater, and the limitations to root growth under the particular rainfall characteristics (Pla, 2002a). These conditions may be modified by soil and plant management practices as tillage, irrigation, drainage, etc. Moisture availability is determined both by water gains from precipitation and water losses through runoff and evapo-transpiration (Tables 1, 2 and 3).

Table 1. Classification of the climate regime (FAO, 1982) as a function of length of growing period (LGP : days with soil moisture higher than the permanent wilting point)

CLIMATE	**LENGTH OF GROWING PERIOD (LGP) (days/year)**
VERY HUMID	365
HUMID	270 - 364
SUB-HUMID	180 - 269
SEMIARID HUMID	120 - 179
SEMIARID DRY	75 - 119
ARID	1 - 74
DRY	0

Table 2. Available water capacity (AWC) of the soil as a function of effective soil depth and soil water retention capacity (Field Capacity (FC) – Permanent Wilting Point (PWP)) (Θ: Volumetric soil water content)

EFFECTIVE SOIL ROOTING DEPTH (cm)		**FC - PWP (Θ)**	
		0,20	**0,40**
25	**AWC (mm):**	50	100
50	**AWC (mm):**	100	200
100	**AWC (mm):**	200	400

Table 3. Length of potential growing period (LGP) during the year, under a semiarid Mediterranean climate as a function of climate variability (total rainfall and distribution), available water capacity of the soil, and % of rainfall losses as surface runoff (*year with rainfall highly concentrated in a few storms at autumn-winter time)

YEAR	**RAINFALL (mm/year)**	**RUNOFF (% rainfall)**		**AVAILABLE WATER CAPACITY (mm)**			
				50	**100**	**200**	**400**
DRY	313	0	**LGP** (days/year):	91	95	95	95
		50	**LGP** (days/year):	65	65	65	65
AVERAGE	522	0	**LGP** (days/year):	151	197	205	205
		50	**LGP** (days/year):	122	132	132	132
HUMID*	785	0	**LGP** (days/year):	194	208	228	267
		50	**LGP** (days/year):	183	196	200	200

In the arid and semiarid Mediterranean climate, the rainfall is highly variable among years and during the year, and usually occurs in erratic storms of short duration and high intensities. The concentration of rainfall in a relatively cool season (autumn and winter) permits reliable cropping in areas with annual rainfall as low as 330-400 mm (see Table 3). Under non-protected soil surface, associated to some intensive agricultural practices and overgrazing, extra precipitation in winter, occurring in intense episodes, may not be stored in the soil, but lost as runoff (Pla and Nacci, 2001). These factors increase the risks of land degradation leading to desertification processes.

The previewed effects of global climate changes would mainly affect hydrological processes in the land surface, mostly related to the soil water balance. In terms of ecological and social impacts of climate change, changes in moisture availability are more important than changes in precipitation alone. Low levels of moisture availability are associated with droughts and desertification. Reductions in mean annual rainfall leads to drier conditions, but increase in climate variability during the year, or increasing frequency of very dry years, could be equally or more important. Therefore, the term aridity for evaluating desertification, instead of only considering average rainfall conditions, would be more appropriate if it also consider variability through the whole hydrological cycle as well as climatic variations and fluctuations.

Human activities leading to land desertification processes may affect soil hydrological processes more than the previewed climate changes, or may increase the influence of those changes (Pla, 2001). Forests usually regulate stream flows, protect land from erosion, reduce flooding in adjacent areas, minimize the silting of rivers, canals and dams, and contribute to a stable hydrology essential for providing stable sources of water for human needs and irrigated agriculture. This water balance may be drastically upset by deforestation and forest fires, and especially by the consequent land degradation. The supply of available water may decrease irreversibly under unchanged soil properties and stable hydrological soil parameters due to reduced water income, increasing water consumption, or both. Under unchanged water income by rainfall, the hydrological parameters of soils may change irreversibly as a result of soil degradation (sealing, compaction, erosion, decreased water holding capacity, etc), leading to the same effects of decreasing available water supply (see Table 3).

Irrigation causes drastic changes in the regime and balance of water and solutes in the soil profile, which may result in soil salinisation, one of the processes of soil degradation leading to land desertification. The salinity problems are a consequence of salt accumulation in zones and depths where the soil moisture regime is characterized by strong losses of water by evaporation and transpiration, and by reduced leaching of the remaining salts. The salt accumulation may conduce to a partial or complete loss of soil capacity to provide the required amounts of water to plants, changing fertile lands to deserts (Pla, 1996).

From the previous arguments, it follows that approaches based on water balance models are the more adequate to predict the reliability of the water supply for a plant during its growth. This would be the main basis for determining the suitability of the land for various uses under given conditions of management. There is required research into the basic hydrological processes of land degradation, including climate and soil data. Research is also required on the hydrological changes as a result of various alternative land uses and agricultural systems and practices. The degree of aridization of soil may be quantitatively determined in terms of certain physical properties and water regime of soils (annual supply of available water in the root zone), using soil hydrological parameters. Therefore, basic research in hydrological processes, including climate influences, must precede monitoring of desertification, because we cannot know what to monitor if we do not understand those basic processes and their impact on desertification.

ASSESSMENT OF DESERTIFICATION IN THE MEDITERRANEAN REGION

A large scale integrated assessment of land/soil degradation and desertification in the Mediterranean region is required, in order to formulate the related prevention and mitigation strategies. Assessments should begin at the local levels, rather than begin at the global or regional levels. The assessment must include past trends, current state and prospective development of soil degradation and land desertification, which should be based mainly in soil hydrology related indicators. The most serious constraints are due to the soil data provided by the national soil surveys, which is mainly static information without any indication on changes and trends, very important for environmental protection purposes. There are also required soil monitoring systems, which aim to deliver information on changing soil parameters, important for soil functions, based on systematic sampling and measurements.

Rainfall, which is very variable in the arid and semiarid Mediterranean climates, becomes the most fundamental data source for monitoring desertification. Also there is required a systematic tracking of vegetative production and soil conditions. A watershed approach for the biophysical resources would help to effectively integrate the information for estimating degradation processes. For tackling large watersheds, it is recommended to carry out first a reconnaissance level analysis of the problems to identify the areas that need focused attention, and then launch a detailed analysis in the targeted small areas.

Assessment and monitoring of desertification have the primary objective to forewarn about some impending crisis of land degradation and desertification, as well to suggest some preventive and remedial measures. These objectives cannot be met without a proper understanding of the processes responsible for desertification, which is the main limitation with the empirical methods generally used presently for assessing desertification and land degradation. There are required other methods, based on hydrological evaluations, to evaluate the problem.

The most commonly used methods for assessing desertification include:

- Field monitoring.
- Productivity changes.
- Sample studies based on field criteria and opinion of land users.
- Expert opinion.
- Remote sensing.
- Modelling.

None of them could be used alone, some need calibration, and others depend on subjective criteria, or are very expensive to be used extensively and continuously.

In most of the cases a weak knowledge of the hydrological processes involved and of the nature of desertification and the inadequacy of the methods for the assessment and monitoring of such processes hampers the adoption of integrated use of soil and water resources and of management policies and rehabilitation programs (Pla, 1998).

It has been proposed to use a set of indicators for assessment of desertification, taking into consideration the particular natural and socioeconomic aspects (Rubio and Bochet, 1998). Desertification is such a complex process that a single indicator will not be adequate to represent the great number of interrelated components. Indicators of desertification must be able to value the conditions and changes of quality and state of such process, and must provide means to compare trends and progress over time of desertification in different scenarios of climate, soils and land use. This requires a holistic, multidisciplinary approach.

Some desertification indicators that have been used include:

- Rainfall.
- Aridity index.
- Drought index.
- Vegetation cover.
- Soil depth.
- Slope.
- Infiltration capacity.
- Population density.
- Grazing intensity.

Oversimplified indices like drought, using climatic maps; vegetation cover, using satellite imagery, and others, which fluctuate year after year, have limited diagnostic criteria (UNCCD, 2003). When mostly qualitative indicators are used, elements of subjectivity are many times involved in the assessment of desertification, depending on interpreters experience or bias. There is a need for searching for more acceptable and easily determinable criteria that are measurable.

So far, Global Assessment of Human-induced Soil Degradation (GLASOD) methodology for identification and mapping of degradation categories (ISRIC-UNEP, 1990), that puts more emphasis on impact of degradation on productivity than on the degree of degradation, has been a methodology widely used. This methodology can not show separately different degradation classes and their severity, due to the poor spatial resolution of the small-scale maps. It would be necessary to use mapping at larger scales, where the areas under different degradation classes and severities could be represented separately, in order to be able to use indicators of desertification for the ultimate objective of understanding the different land degradation processes and for finding area-specific solutions to the problems.

It may be concluded that in order to assess and to predict adequately desertification there are required:

- Collection of sufficient field observations and data, mainly of hydrological nature, to reflect temporal and spatial conditions and variations.
- Identification of the causal processes.
- Development, calibration and use of simulation models that can predict future changes.

In all cases the criteria used must be clear, relevant, environmentally specific and scale-specific.

MODELLING FOR ASSESSING DESERTIFICATION

Most of the existing indicators of desertification, based mainly on climate and vegetation cover, have limited diagnostic criteria. The use of the so called soil quality attributes and indices to assess the vulnerability of soils to degradation and land desertification processes, scored from empirical judgements, do not allow relating the evaluation to the overall sustainability of alternate land use systems for production, control of environmental impacts, etc. Other methods are needed to evaluate the problem.

A hydrological approach to the assessment and prediction of the conservation of soil and water resources against degradation and desertification processes has proved to be essential for an adequate development, selection and application of sustainable and effective land use and management practices (Pla, 1998; 2001). The increased requirements of more quantitative results in probabilities and risks of soil degradation and land desertification, and its influence on crop production and environmental damage may be partially satisfied with the use of modelling, where the large number of important variables involved in the desertification processes, and their interactions, may be integrated.

Analysis and suitable modelling of data and processes helps to find out the trends in desertification and the responsible factors, under different bio-physical and socio-economic settings. Modern techniques of digital remote sensing and geographical information systems (GIS) may be very helpful in the analysis and processing of the original and generated information. Modelling desertification requires a previous identification of the main desertification processes. Appropriate models must help in gaining more insight into the processes and on the understanding of the system as a whole. Although models cannot replace deciders, they supply them with valid and quantitative alternatives, required to take successful actions. In any case, simulation modelling has to be used with caution and should be based on sufficient local information. Field-based information is essential, and data obtained through digital remote sensing need to be verified in the field to be useful (Pla, 2002b).

Empirical models, such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and its revised version RUSLE (Renard *et al*, 1991) have been commonly used in the countries of the Mediterranean region, frequently without verification, for large scale water erosion (one of the more important soil degradation processes leading to desertification) risk mapping. Although the outputs and mapping using GIS may be impressive, they can hardly be used with a guarantee of success for development or prevention of desertification purposes (Pla, 2002b). There are required other non empirical modelling approaches mainly based on soil hydrological processes, deduced from soil hydrological properties together with historical rainfall records, under different scenarios of changing climate, soil properties, topography, and land and crop management, which may be combined in computer-based programs. The bio-physical data, mainly of hydrological nature, may be taken as surrogates for human impact, but in some models the social economic data are also fed into calculation procedures with variable success.

Simulation models based on hydrological processes may be very helpful to integrate and convert the measured or estimated soil, climate, plant and management parameters into predicted soil water balances and soil moisture regimes for each particular combination of them, actual or previewed (Pla, 2002b). These models not only help to understand the complex process of desertification, but they may also serve as decision-making tools to reduce or to avoid negative environmental impacts leading to desertification under different and changing scenarios (Richter and Streck, 1998).

Hydrological approaches allow combining the characteristics of climate with the characteristics of soils and landforms and land-use systems, for interpretation and prediction of land desertification hazards. When applied to a series of scenarios of land use and potential environment and climate change impacts, the results can be used by decision makers for future land use planning and implementation. This approach also makes the extrapolations more soundly based and provides a scientifically solid base which leaves little space for subjective interpretations leading to alternatives for different land use and management for agricultural and non-agricultural purposes. Modelling hydrological processes has proved to be a very reliable tool for evaluation and prediction of land degradation processes for guiding planning strategies for soil and water conservation and management practices, under very different climate, topography, soils, cropping and management conditions (Pla, 1997; 1998; 2001; 2002a).

Figure 1 shows an adaptation of the flow diagram, which was the basis for the development of the simulation model SOMORE (Pla, 1997), based on hydrological processes. This model simulates the evolution of the soil water balance in the soil profile with a time step of one day, using easily obtainable soil and climate data as input. It may be used to predict the soil moisture regime, including water logging, rainfall losses by surface runoff, and surface and internal drainage, under different conditions of soils, topography, climate, vegetation, crops and management. The predictions may be used to identify the more probable land degradation and desertification processes, and for the selection of the best alternatives, with more probabilities of success, and for the assessment of environmental impacts, positive or negative, of soil and water conservation practices for each combination of soils, climate and topography.

Figure 2 shows the flow diagram which was the basis for the development of the model SALSODIMAR (Pla, 1996), which integrates the influence of climate, crops, soils, groundwater depth and composition, irrigation water quality, and irrigation and drainage management on the desertification by salinisation, sodification and contamination of soils and groundwater. It may be useful, among other things, to preview the best alternatives for the use and management of the available soils and waters, preventing the process of desertification by secondary salinisation. It has proved to be reasonably good to predict salinisation problems and to deduce the best alternative practices for irrigation and drainage to prevent salinisation and sodification and other related environmental problems leading to desertification.

Figure 3 shows how the simulation models based on hydrological processes, used for the evaluation and prediction of potential soil and water degradation processes causing land desertification, may be integrated in the planning strategies leading to sustainable land use, management, and soil and water conservation practices, under different and changing scenarios (Pla,2001; 2002b)

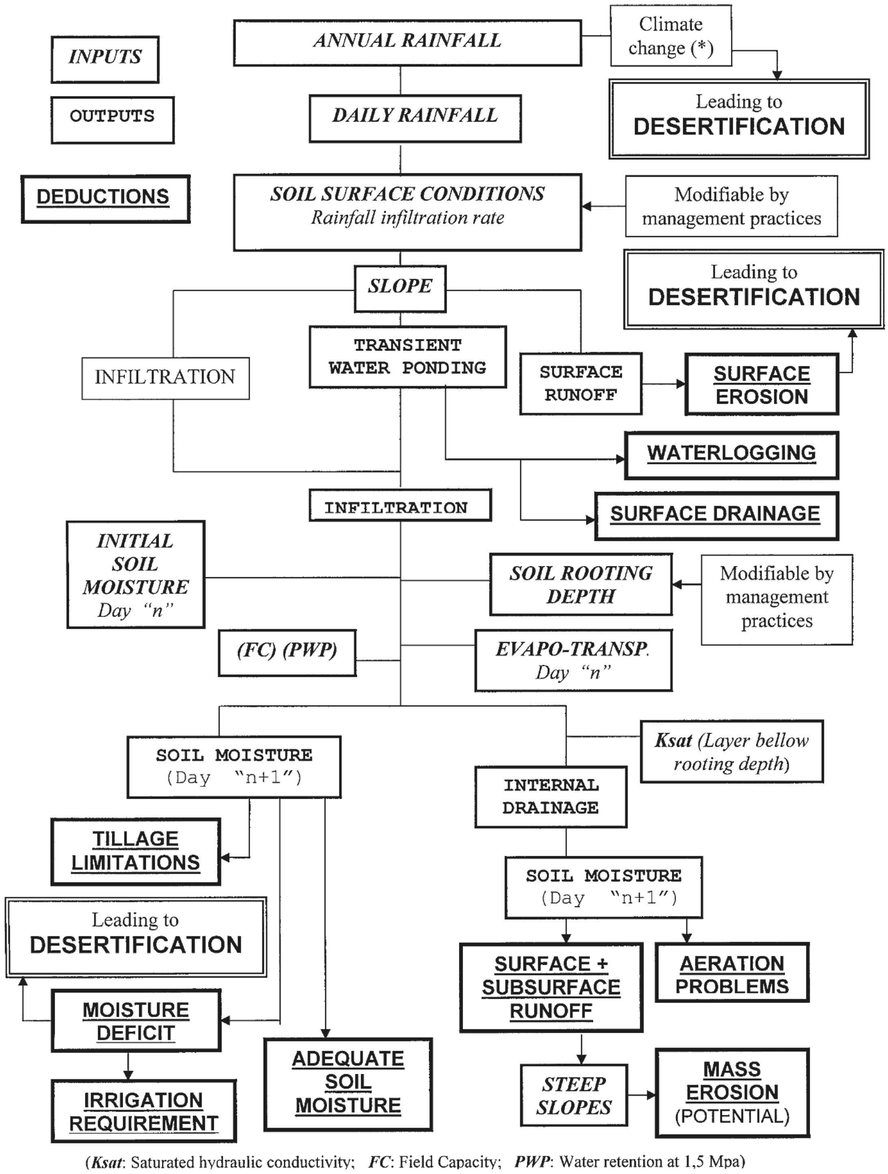

Figure 1. Flow diagram of a conceptual model based on hydrological processes (SOMORE), to predict the soil moisture regime and to assess the potential soil and land degradation and desertification processes (adapted from: Pla, 1997). (in the Mediterranean region)*

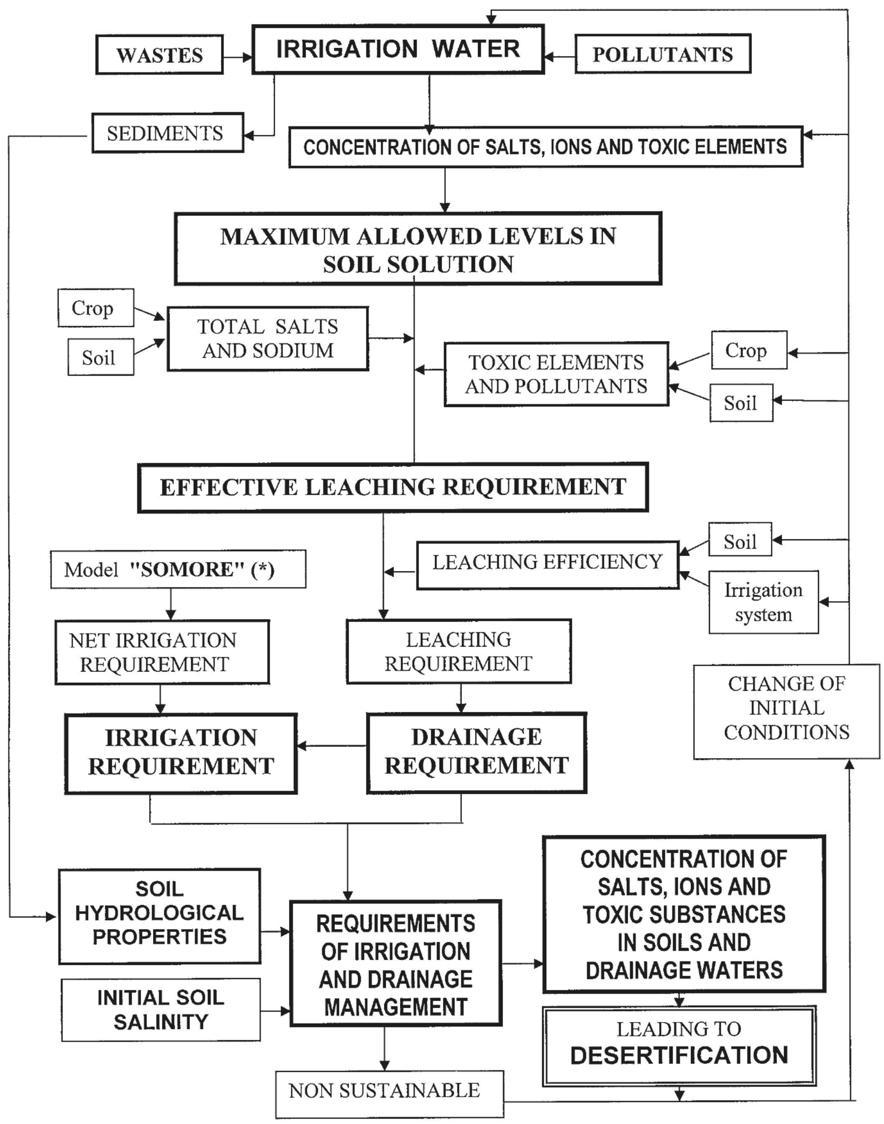

*Figure 2. Flow diagram which was the basis for the development of the model SALSODIMAR (Pla, 1996) for evaluating and predicting land degradation and desertification by salinisation, sodification and contamination of soils and water (*see Figure 1)*

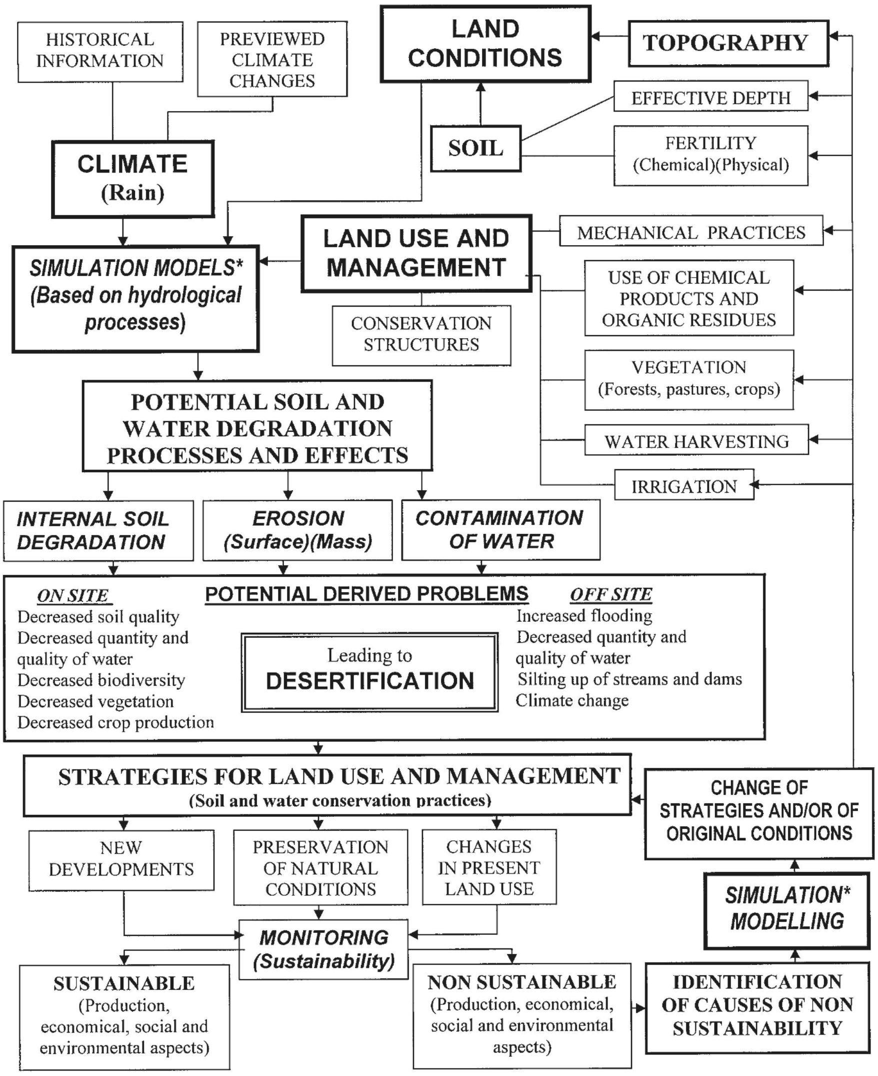

*Figure 3. Role of simulation modelling based on hydrological processes (*see Figures 1&2) for evaluating potential soil and land degradation and desertification, and for planning land use, management and soil and water conservation practices (adapted from: Pla, 1991; 2002b)*

CONCLUSIONS

Assessments of desertification processes must be able to provide value of conditions and changes of quality and state of such processes, and provide means to compare trends and progress over time in different scenarios of climate, soils and land use. To reach such objectives, the indicators for land desertification should determine and analyse the cause-effect relationship involved, facilitating comparisons between biophysical and social economic causes and impacts of land desertification, and should be based on qualitative evaluations and quantitative measurements feasible from the technical, economical and institutional points of view.

Relationships between soil characteristics and soil hydrological properties are the beginning point to simulate or to predict dynamic soil desertification processes and their effects. Therefore, a hydrological approach to the assessment and prediction of conservation of soil and water against desertification processes, is essential for an adequate development, selection and application of sustainable and effective land use and management practices. Weak knowledge of the hydrological processes involved, and of the nature of desertification, and the inadequacy of methods for assessing and monitoring of such processes, usually hampers the adoption of integral resources use and management policies and rehabilitation programs in areas subjected to desertification in the Mediterranean region.

Parameters of the available water supply, deficit of soil water and soil water regime, single or together, may serve as reliable measurable criteria of the degree of soil aridization in time and space. Their practical utilization for the assessment of the degree of land desertification will require research on the water regime of soils under desertification, using an adequate methodology. Without such research, other considerations of degree of desertification will be mostly subjective, being based on indirect criteria and not in the direct measurement of hydrological parameters.

Assessment of land desertification processes must be complemented with monitoring, through systematic permanent or periodic observations and measurements of climate parameters, biological productivity and water regime of soils.

The evaluation of the hydrological processes, under different scenarios and changing climate, soil properties and land use and management, with flexible simulation models based on those processes may help to predict and to identify the biophysical causes of desertification at local, national and regional levels in the Mediterranean region. This is a required previous step for a rational land use planning, and for the selection and development of short and long term strategies and technologies to reduce or to control land degradation processes leading to desertification, and to the related social economic and security problems.

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THE USE OF ALTERNATIVE FUTURES IN A STRATEGY TO ASSESS THE LIKELIHOOD OF LAND DEGRADATION LEADING TO INCREASED SUBSEQUENT POLITICAL INSTABILITY

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ABSTRACT

As stated by the United Nations Convention to Combat Desertification (UNCCD), desertification or land degradation is at the root of political and socio-economic problems and poses a threat to the environmental equilibrium in affected regions. That desertification and political instability are interlinked should not be a surprise, the UN states that half of the 50 armed conflicts in 1994 had environmental causal factors characteristic of drylands (i.e., land degradation). One example cited states that the land's loss of productivity exacerbates poverty in the drylands, forcing its farmers to seek a way of living in more fertile land or cities. In fact, over one billion people are affected as a direct consequence of desertification including 135 million people who are at risk of being displaced.

The physical, biological and social causes of desertification that lead to grave human impacts are interlinked with significant feedback mechanisms. Soil salinization, for example, may result from unsuitable irrigation practices. Changes of vegetation from perennial grasses to shrubs and to annual grasses and forbs might result from overgrazing. Increases in poverty and human out-migration might result from declining agricultural productivity caused by salinization and overgrazing.

Because poverty forces the people who depend on land for their livelihood to overexploit the land for food, energy, housing and source of

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income, desertification can be seen as both the cause and consequence of poverty. Any effective mitigation strategy must address poverty at its very center. It must take into account the social structures and land ownership as well as pay proper attention to education, training and communications in order to provide the fully integrated approach which alone can effectively combat desertification.

Seeking solutions to such complex problems requires appropriate technologies and common sense. This paper suggests a technique, alternative futures analysis, to model the likelihood of future land uses in a given region undergoing desertification or at great risk to desertification and to develop an understanding of the risk to political instability coming from each of the alternatives. Furthermore, alternative futures analysis provides a technique (and communication strategy) for illustrating possible conflicts as well their causes and potential solutions. Such a strategy would help local, national and regional land managers, working with their constituent stakeholders to mitigate such effects. A framework for a pilot project employing this technique is presented.

INTRODUCTION

Desertification is defined as "Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (UNCED, 1992). The term "desertification" was first used in the 1940s (Aubreville, 1949) and the phenomenon itself is the consequence of long-term, high intensity exploitation of natural resources exacerbated by changes in the natural system (for example, climate change).

In the late 1960s and early 1970s a drought in Sub-Sahelian Africa captured world attention and resulted in the death of over 250,000 people (Reynolds and Stafford Smith, 2002) and the migration of many thousands more. The problem of desertification and its global significance was acknowledged in 1977 when the United Nations held a Conference on Desertification, and developed a Plan of Action to Combat Desertification. This was followed by the United Nations Conference on Environment and Development in 1992, which resulted in the United Nations Convention to Combat Desertification (UNCCD), which was formally adopted in 1994. To date over 190 countries have signed the Convention, and desertification has become a well-known term – although the implications of its environmental and social consequences are not yet fully recognized.

The UNCCD considers desertification a threat to environmental equilibrium, a cause of socio-economic problems, and a significant factor in political instability (www.unccd.int). In 1994, according to UN reports, half the 50 armed conflicts were associated with dryland areas suffering from the effects of desertification. In many areas loss of productivity results from the exploitation of dryland resources beyond the point of recovery, and almost a billion people worldwide are undernourished (Tickell, 2003). A total of 135 million people are at risk of becoming refugees as a consequence of desertification (www.unccd.int), and an additional one billion are also at risk.

DESERTIFICATION MECHANISMS

Desertification processes comprise physical, biological and social causes and effects, which are interlinked with significant feedback mechanisms. For example: dryland soils are characterized by low levels of biological activity, organic matter and aggregate stability – which can easily result in a breakdown or decline of soil structure, accelerated soil erosion, reduction in moisture retention and increase in surface runoff (Williams and Balling, 1996). Reduction in plant cover may result, which will exacerbate the processes of soil deterioration, leading to a change of scale in the spatial distribution of soil resources (de Soyza *et al*., 1998) an increasingly 'patchy' landscape and a decline in sustainability that is difficult or impossible to reverse (Schlesinger *et al*., 1990). A landscape including large patches of bare ground caused by reduced plant cover is susceptible to erosion, and fine soil particles that are essential to the growth of natural vegetation and crops are blown or washed away. Physical changes in soil structure result from compaction, crusting and water logging, and are exacerbated by human land use pressure and widespread irrigation (Middleton and Thomas, 1997).

Similarly, a change in vegetation community structure and reduction in cover may be both a catalyst for and consequence of desertification processes (Le Houérou, 1996). A shift from grassland-dominated to shrub-dominated rangeland is a common phenomenon (e.g., Ludwig and Tongway, 1995; Milton and Dean, 1995) and is generally associated with increased soil runoff. The main causes of this vegetation change seem to be grazing and fencing, and alterations to the natural fire regime, in association with climatic variability (Mouat and Lancaster, 1996).

The World Atlas of Desertification (Middleton and Thomas, 1997) suggests that overgrazing, improper agricultural practices, overexploitation of vegetation and deforestation are the four most significant causes of soil degradation and desertification, although bio-industry plays a locally important role in some countries. Soil degradation may result from displacement (wind and water erosion) or internal deterioration by chemical or physical variables (Oldeman, 1988). Erosion of soil by water results in loss of topsoil and subsequently leads to changes in the landscape. Loss of topsoil has an impact on both natural vegetation and cultivated crops (www.unccd.int) and is the dominant erosion process in Africa (Middleton and Thomas, 1997, among others). A change in soil nutrients and a patchy distribution of nutrients at the landscape scale is a consequence of desertification (Schlesinger *et al*., 1990) and in some cases may be partially due to erosion of fine particles by wind and water (Schlesinger *et al*., 2000). Wind erosion is most severe in areas that have been disturbed by human activity - for example, by grazing pressure that reduces plant cover. In the grazing context, reduced plant cover results in overexploitation of remaining vegetation, and, eventually, a reduction in animal health. Where crops are planted, some parts of the field may have sufficient soil nutrients for the crops to grow, while other areas remain as bare ground or produce stunted and infertile plants. Reduced yields of food crops result in a decline in human health. These scenarios are played out worldwide where desertification and its affects are a threat, and as both people and animals decline in condition, a further "patchiness" is added to the landscape with areas closer to the local communities being more heavily exploited than those further away.

A declining biophysical system, at risk for desertification, may not be able to produce the goods and services necessary for a sustainable socioeconomic system (Reynolds and Stafford Smith, 2002). This results in food shortages and hunger, and overexploitation of resources in an attempt to produce more food. The effects further deteriorate the land condition. Declining human health, and in some pastoralist societies, declining wealth as animal condition deteriorates, saps the will to succeed and to try alternatives and the inevitable consequence is a lowered standard of living and loss of human dignity. Social systems, stable when life is good, are threatened; and mechanisms maintaining justice – in its broadest sense- are questioned or fail. Once initiated, this cycle is difficult to break. Desertification is linked to poverty (www.unccd.int; Glantz, 1994; Reynolds and Stafford Smith, 2002) and tends to result in out-migration, initially of young people and men. This changes family structure and places burdens and constraints on the remaining women, children and elderly, which in turn changes patterns of land use and may further exacerbate desertification (www.unccd.int). Even without migration as a factor in the equation, poverty results in overexploitation of the land – not only for food but also for energy, housing needs and a source of income. Desertification is both a cause and consequence of poverty, it results in reduced crop yields, increased distance to potable water and fuelwood, poor animal and human health, hunger, hopelessness and desperation.

This process may be deductively summarized as follows:

- Land degradation leads to poverty. Poverty leads to social unrest/instability and subsequently a risk to security. Therefore land degradation is a potential risk to security.

THE QUESTION

Why do some people threatened with or affected by desertification pose a risk to security while others do not? In many cases people are passive. Possibly blaming nature or governments for the effects of desertification, and ignoring their involvement in the chain of events. In many cases people in entire regions move to cities or neighboring towns (Glantz, 1994), where resources may be no more abundant, and where they are outsiders with different customs and beliefs. At this point the socio-economic results of desertification are communal rather than individual, and people's reactions may be similarly different in scale. If charismatic or influential leaders are available – disillusioned, disenfranchised and desperate people may take the law, and action, into their own hands – and political stability and security become threatened.

Tickell (2003) argues that damage to vegetation and soils and disruption of the hydrologic cycle characteristic of desertification may alone be one of the main drivers for sudden or drastic change in human condition and response. He identifies global trends of urbanization, differential rates of population increase and the widening gap between rich and poor, and proposes that desertification may aggravate this situation, resulting in tensions within and between communities. Thus desertification affects the entire biophysical system, and the wider consequences go beyond poverty and inequity, to include weakening or breakdown of social and political institutions (Tickell, 2003).

Among the social consequences are migration and the creation of refugees. Environmental refugees are typically poor and need shelter, food and medical care. Additionally, they may bring different customs, religions, agricultural practices and diseases with them, and many governments, at national or local scale, simply do not have the resources to deal with this situation (Tickell, 2003). An influx of refugees into an area already experiencing environmental stress (such as desertification) and depletion of resources is, according to Liotta (2003), likely to result in "ethnic" clashes and infrastructure collapse. Ultimately, this is a potential risk to security.

Conflict is one of the five possible outcomes of environmental stress (desertification) proposed by Brauch (2003), the others being man-made and natural disasters, migration, crisis and efforts at conflict resolution. For dissident, or conflict activity to be successful, and therefore a serious risk to security at more than a strictly local scale, some form of organization is needed. People affected by desertification may reach the point where they feel they have nothing to lose, and become particularly vulnerable to dissidents and agitators. In the context of migration, refugees, overcrowding and forced co-existence of differing groups, social stability declines and security risk increases. So if "organization" is the answer to the question posed above, then perhaps it is also the solution. We suggest a technique that would highlight in a predictive manner the last of Brauch's outcomes – conflict resolution – and would also help to address the causes of desertification and promote sustainable development of dryland regions.

A POTENTIAL TOOL FOR CONFLICT RESOLUTION

An alternative futures assessment is a modeling technique that involves local stakeholder groups in decision-making. The spatially explicit futures models address human-environment interactions through empirical representation of human-induced change across time; past patterns and correlates of change are then used to "project" alternative future scenarios. Especially important to the future scenario modeling effort is consideration of stakeholder priorities to indicate viable alternative land-use options, which leads to the sharing of differing perceptions and views. Alternative futures analyses are facilitated by outsiders, or persons not immediately involved in the situation. They operate at the landscape or regional scale, over a typical period of 20 to 50 years, involve both environmental and demographic data and are designed to specifically address local issues and concerns.

Alternative futures analyses have been conducted in many parts of the world. Examples in North America address issues such as agricultural policy (the Iowa corn belt), recreational opportunity (Monroe County, Pennsylvania), urban development and ecological preservation (the region of Camp Pendleton, California), water (the Upper San Pedro River Basin in Arizona and Sonora) and diverse land use and planning options (Southern Rocky Mountains, Alberta, Willamette River Basin, Oregon, and others).

The underlying hypothesis directing the research for the Camp Pendleton study was that major stressors causing a change in biodiversity are related to urban development (Steinitz *et al*., 1996; Adams and Steinitz, 2000). With over 200 plants and animals listed as rare or endangered, the region is one of the most biologically diverse environments in the continental United States (Steinitz *et al*., 1996; Adams and Steinitz, 2000), and is also one of the country's most desirable places to live and work. Change was studied at four spatial scales and over a time period ranging from 15 to 25 years. Four ecological process models were developed and used to assess each of the five scenarios from the perspective of soils (agricultural productivity), hydrology (floods and soil moisture), fire (vegetation maintenance and risk) and scenic preferences.

The ten scenarios identified by the alternative futures analysis in the Upper San Pedro River Basin all resulted in lowered groundwater levels and increased drying of the river (Steinitz *et al*., 2003) and all impact the ecological sustainability of the region. This region of southern Arizona and northern Sonora (Mexico) was historically dominated by grassland ecosystems, which have gradually been replaced by shrub-dominated communities and fragmented by development (Mouat and Lancaster, 1996). Although ranching is still important in the region, ecotourism, mining and residential development have increased, and result in a range of perceptions among local stakeholders concerning priorities for the region's future.

An alternative futures analysis for Kuiseb River Basin in western Namibia is being discussed at the framework stage to determine its viability. Namibia is facing a number of social and environmental pressures that threaten the well-being and livelihoods of its people, and its natural environment. These social and environmental pressures are closely interrelated, partly as a result of one of the world's highest population growth rates. The environmental pressures reflect demographic changes, and include improper grazing techniques which threaten the shrub savanna ecosystem, increased demand from communal or subsistence farmers which threaten soil productivity and upstream damming of rivers which affects surface and groundwater regimes. Partially as a result of these patterns of human behavior, desertification processes such as change in vegetation composition and cover are causing serious concern and economic hardship to several sectors of the population.

An alternative futures analysis uses GIS as a tool to conduct simulations using a series of process models, each of which is grounded in theory relevant to its own particular discipline. The models used vary with each analysis. For example, in some studies fire ecology may be sufficiently important to demand a model whereas in others fire may be part of a vegetation change model. The methodology was, in part, developed by Carl Steinitz, Harvard Graduate School of Design (1990, 1993), and considers principles of landscape architecture. Models are developed to answer six questions addressing the landscape in terms of present condition, structure and function and the projected effects of change in landscape components.

These six questions form the framework of each analysis (Steinitz *et al*., 2003):

- How should the state of the landscape be described in content, space and time?
- How does the landscape operate? What are the functional and structural relationships among its elements?
- Is the current landscape working well?
- How might the landscape be altered, by what policies and actions, where and when?
- What difference might the changes cause?
- How should the landscape be changed?

The analysis is conducted by asking and answering each of the above questions at least three times using models of representation, process, evaluation, change and impact. The result is a decision, which results in another set of models to drive subsequent question-answer processes in a manner analogous to an "if-then-else" loop. The analysis uses existing data where possible and contains a component of cultural knowledge and stakeholder input that has varied in importance in previous and ongoing analyses, but would be strongly implemented in a study where the potential risk to security was a direct concern.

The operational framework for an alternative futures analysis is shown in Figure 1. The stakeholders include people living, owning land or working in the area, plus managers, policy makers, the media, NGOs, aid organizations – anyone with an interest or involvement. The success of an alternative futures analysis depends on stakeholder participation, in sharing knowledge and experience of land use strategies as well as issues and future concerns. In a situation where different social structures involving ethnicity, religion, land ownership strategies, women's participation or other potentially divisive variables are a factor, representatives from all groups should be part of the process. With a focus on desertification issues and maintaining sustainability, there is a unifying purpose to the alternative futures analysis process that may transcend social and economic issues. Possible conflict situations would be illustrated before they arise, their cause and potential solution would be subjects of discussion, and the situation would be defused. The overall result of the analysis is an identification of likely alternative futures for the area, and through GIS modeling, a visual and statistical assessment of the impact of each of the futures upon the environment.

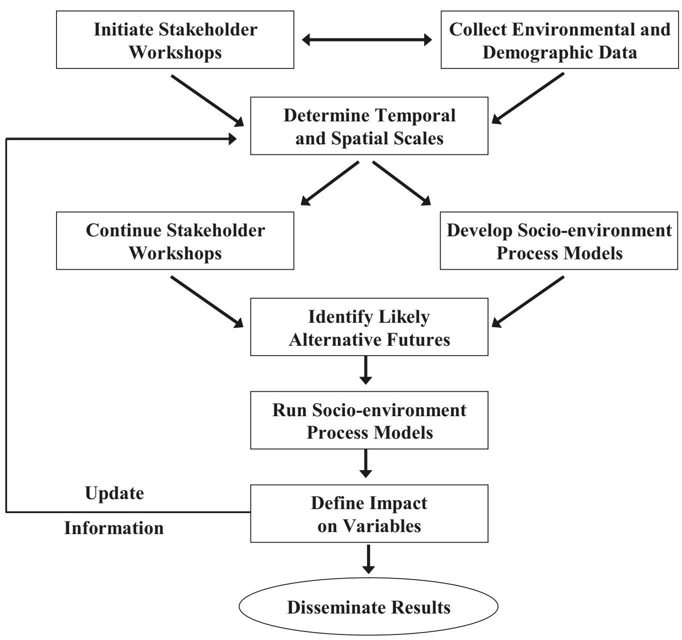

Figure 1. Framework for an alternative futures assessment

An alternative futures analysis provides an opportunity for policy makers and politicians to understand potential future situations and mobilize appropriate agencies to deal with them. It gives them a technology to assist in developing strategies to achieve desirable future land uses in a socio-economic and biophysical context. Additionally, the GIS-based visualization of the potential impact of land use alternatives upon the landscape is material that can be used at local, regional and national level for presentations, information sharing, education and lobbying.

IMPLEMENTATION OF AN ALTERNATIVE FUTURES ASSESSMENT – A HYPOTHETICAL EXAMPLE

In an area susceptible for desertification, an alternative futures assessment would indicate the land use and land management strategies most likely to result in sustainable development, and would identify locations where desertification is a threat and therefore security risk is highest.

Three hypothetical scenarios are diagrammed in Figure 2, showing how variables involved in or affecting the desertification equation may impact social stability over time. Each of the hypothetical countries has a driver for change: drought, refugee influx or inappropriate land use. Furthermore, the land condition is different for each country and the interaction between this condition and the driver for change stresses the availability of food. In turn the amount of food available influences social stability. All these statements are true to a limited extent and the question is how well can each country cope given a specific driver of change? The potential answers to this question are usually diverse, but, for illustrative purposes, a hypothetical worst case answer for Country 3 (rf. Figure 2) will be described.

In the case of Country 3, the government relocated a community displaced by construction of a dam. The people were moved to a neighboring province, into a relatively sparsely populated area with a pastoralist economy. The immigrants were installed in their newly constructed homes, issued with seeds for a cash crop and told that the government would pay them well for a good yield.

Fragile semi-arid soils in the area were inherently incapable of sustaining an annual crop, and rainfall was unreliable. Over a period of several years, the immigrants tried to develop friendships with the pastoralists but they were perceived as intruders and land thieves. Areas cleared for crops generated dust, the soil surface baked into a crust, and immigrants became desperate. At this point there was negligible social stability among them, and their growing sense of injustice began to affect the whole region. Environmental and social conditions deteriorated rapidly, and anti-government rallies began.

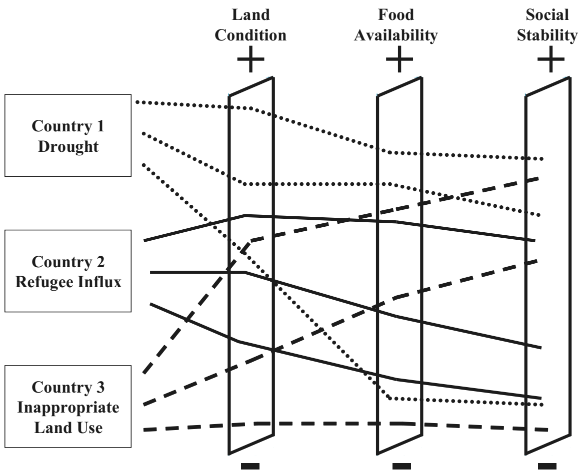

Figure 2. Trajectories toward social instability in three hypothetical countries experiencing social or environmental problems. At first, in each country, things are unchanged and social and political stability are good (top line from each box). As each detrimental variable takes effect, land condition deteriorates, food supply diminishes, and political stability becomes uncertain (middle line from each box). Finally, (lowest line in each box) when it is basically too late to alleviate the situation, the land is no longer productive, food is unavailable and political stability is negligible – resulting in a high risk to security

This hypothetical situation could have been averted altogether, or considerably reduced by the implementation of alternative futures analysis techniques. It is important that the process be facilitated by an outside observer, so ideally, as the cash crop failure became apparent an NGO or non-partisan team would initiate stakeholder workshops and visit with both communities involved, local policy makers and government officials. These interactions would provide an opportunity for both groups to share experiences and talk about differences, identifying potential problems before they become serious issues. In the hypothetical example of Country 3, the question of land ownership and land use rights would likely be of major concern, and may have resulted in new "regulations", being drawn up with everyone's approval. The result of the alternative futures process may also be a reduction in the effects and risk of desertification and plan for a collaborative strategy to maintain regional sustainability. Social stability could have been maintained, and the risk to security minimalized.

CONCLUSIONS

Alternative futures analysis is a technique that integrates environmental and demographic data, providing potential solutions to both environmental and social issues. In the context of political instability and the risk to security associated with desertification, this technique can be used to identify potential conflict situations and evaluate strategies most likely to defuse conflicts before they occur. Designed to address environmental concerns including biodiversity and water resources, alternative futures analysis involves stakeholders of all types and promotes interaction, communication and capacity building.

Poverty is inextricably linked with desertification. Thus, poverty must be addressed when any attempt is made to mitigate or "combat" desertification. Similarly, an understanding of social structures and land ownership traditions must be an integral part of the mitigation process. These issues are recognized by the UNCCD and are actively promoted in National Action Plans in many of the over 190 countries that have ratified the agreement. The scale of the desertification problem appears daunting, and the risk to security considerable, however the development of regional institutions and the fostering of cooperation and overlapping social and political institutions first implemented by Bismark, proved effective in Europe in the 1870s (Liotta, 2003) and may be an effective strategy for this global issue.

Brauch (2000) proposes that organizational dialogues may solve future challenges, and we suggest that alternative futures analysis may be one small component in this process to alleviate the social and environmental effects of desertification and thereby reduce the threat to security.

As a tool in conflict resolution, alternative futures analysis provides a forum for the exchange of concerns, issues and hopes for the future, and a final product that may be used by local leaders to influence managers and policy makers. Importantly, the technique also provides a leadership opportunity for potential dissidents and agitators, and is a tangible expression of "official" (governmental or non-governmental) concern and interest in the problem under investigation, and the people involved. The process empowers people, and provides capacity building so that they have the tools to take charge of their future and the future of the land. As eloquently stated by Reynolds and Stafford Smith (2002) rural people are not the "problem" in desertification, nor are they the "victims", they are part of the whole, integrated system.

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