DESIRE REPORT series

Desertification and land degradation: origins, processes and solutions

A literature review

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This report was written in the context of the Desire project
www.desire-project.eu

World Soil Information

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Chapter 1
Introduction

1. Introduction

Land degradation occurs in all kinds of landscapes over the world. Desertification can be seen as a specific type of land degradation, occurring mainly, but not exclusively, in dryland regions. The issue of desertification has received and continues to receive much attention. This attention was caused, in first instance, by the drought that hit the Sahel in the 1970s. In 1977, through the United Nations Conference on Desertification (UNCOD), desertification was identified as a worldwide problem. The area threatened at least moderately by desertification was stated to be 3.97 billion hectares or 75.1% of the total drylands, excluding hyper-arid deserts (UNCOD, 1977). Also in the popular press, the issue of desertification got attention: 'Spread of Deserts Seen as a Catastrophe Underlying Famine' (New York Times, Jan.8th, 1985); 'Sahara Jumps Mediterranean into Europe' (Guardian of London, Dec. 20th, 2000). Opposed to these, also more critical headlines appeared at times: 'Threat of Encroaching Deserts May be More Myth than Fact' (New York Times, July 23rd, 1991). The United Nations General Assembly declared 2006 the International Year of Deserts and Desertification to spread the awareness of the worlds deserts and the problem of desertification. The UNCCD (United Nations Convention the Combat Desertification) states that nowadays, 250 million people are directly affected and the livelihoods of one billion are threatened by desertification (UNCCD, 2007). In the scientific literature, desertification and related issues are widely and intensively studied and some authors question the notion that desertification is increasing.

It is, for several reasons, almost impossible to give an accurate description of the severity and extent of desertification in the world. Despite extensive research, lack of good information on extent and severity of land degradation in drylands still hampers attempts to determine its significance (Dregne, 2002). Although many different drivers for various desertification related problems have been identified, it is generally accepted that both natural (climate; biophysical characteristics) and human-induced (land use; socio-economic) factors play a role. Also, most scientists agree that participation of local stakeholders (e.g. farmers, local government etc.) is of key importance in the development and implementation of possible solutions. However, often the effects of solutions are not as successful as expected and new, alternative land use and management strategies need to be developed with the experiences of older strategies in mind.

The recently started international project DESIRE (Desertification Mitigation and Remediation of Land, a global approach for local solution) aims to contribute significantly at preventing and reducing land degradation and desertification through development of integrated conservation approaches based on the detailed understanding of the functioning of fragile semi-arid and arid ecosystems. The final goal is the establishment of promising alternative land use and management conservation strategies. One of the first goals is to look at degradation and desertification processes in an integrated way, in order to review the cause and effect links and give the conservation measures a sound scientific basis. See Appendix I for a detailed description of the project.
So-called degradation and desertification hotspots and stakeholder groups have been identified in all countries surrounding the Mediterranean and in 6 non-EU nations facing similar environmental problems. DESIRE aims to produce results that are internationally relevant, but the focus is on the Mediterranean region. Accordingly, this review is strongly focused on the Mediterranean area as well, but its scope is not exclusively limited to it.

1.1. Aims

As a starting point of the DESIRE project, a literature review on desertification has been carried out which is presented here. The aims of this review are:

(1) to give an overview of existing knowledge on desertification from published results of former projects and research;
(2) to assess the evidence of desertification and
(3) to indicate gaps in the existing knowledge that can subsequently be assessed in the DESIRE project.

1.2. Definitions and key concepts

Apart from desertification itself, several important concepts are mentioned in this review. For example: "First of all it is important to recognise that dryland ecosystems are inherently non-equilibrium systems and ecosystem dynamics are essentially event-triggered. Most disturbances, such as rainfall variability and fire, are incorporated in dryland ecosystems during their evolution. However, some disturbances are new or not yet incorporated and may drive the system to qualitatively different new states along irreversible trajectories" (Puigdefábregas, 1998). These concepts are explained here. Also the concept of land degradation and the extent of drylands are discussed briefly here.

1.2.1. Desertification

Over a hundred formal definitions of desertification have been proposed, covering many spatial and temporal scales and representing different viewpoints (Thomas, 1997; Reynolds and Stafford Smith, 2002). The term desertification was first used in West Africa in 1949 by a French forester to describe the way in which it was perceived that the Sahara Desert was expanding to encompass desert-marginal savannah grasslands (UNEP, 1997). Afterwards it was realised that desertification was not only happening in Africa but in dryland areas (see 1.2.3) worldwide (UNEP, 1997). In 1992, UNEP defined desertification as 'land degradation in arid, semi-arid, and dry sub-humid areas resulting mainly from adverse human impact' (UNEP, 1992). It was recognised that such changes should be "effectively permanent" (Abel and Blaikie, 1989), distinguishing it from short-term, reversible changes such as drought. It should be noted that while many forms of environmental change are theoretically reversible over short time-frames (e.g. thorny bush encroachment that out-competes more productive forage), socio-economic constraints may render the change *effectively* permanent (e.g. if land users do not have the capacity to remove bushes and exclude livestock to facilitate recovery). In 1994, the UNCCD broadened the definition by adding climatic fluctuations. This latter became the most widely used definition, which is the one used in this review as well: '***land degradation*** *(see 1.2.2)* ***in arid, semi-arid and dry sub-humid areas resulting form various factors, including climatic fluctuations and human activities'*** (UNCCD, 2006). *Land* in this context includes, according to the UNEP (1997), soil and local water resources, land surface and vegetation including crops. Thornes (1996) describes this as the bio-productive system comprising soil, vegetation, other biota and the ecological and hydrological processes that operate within the system.

The definition of the UNCCD includes a wide range of conditions and processes which ultimately lead to the onset of desert conditions (Wainwright, 2004). It has been criticised as being too vague and ambiguous (Juntti and Wilson, 2005). These authors state that although human activities are mentioned, the emphasis is on biological processes and technical aspects, thereby sidelining political, economic and socio-cultural dimensions. Other authors and projects have included specific processes in the definition, e.g. Project DM2E specifies that the term desertification refers to the combination of economic, social and climatic processes that cause an imbalance in ecosystems and the reduction or the destruction of the biological potential of soils (Wainwright, 2004). Thornes (2002) states that, if anything, it would be useful to incorporate at least the rural depopulation, especially in the European context, as abandonment of rural areas is a pivotal problem in this region. The EFEDA project includes in the list of causes of desertification, instead of various factors, water erosion, salinization, alkalinization, elimination of plant cover, soil structure degradation, over-exploitation of water resources, cessation of traditional soil conservation techniques and improper land-use planning (Wainwright, 2004). The MEDIMONT project includes the concepts of non-reversibility and the alteration of key components of the soil, vegetation and water system (Wainwright, 2004). They conclude that desertification is a complex phenomenon involving both degradation and recovery processes. Puigdefábregas and Mendizabal (1998), state that desertification is a well-defined process, triggered by changes in climate and socio-economic boundary conditions of affected dryland systems. These changes cause the system to enter an irreversible positive feedback loop of overexploitation of land of which the final outcomes are land degradation and disruption of local economies. They add that desertification is an acute process that occurs at rates several orders of magnitude faster than purely climate-driven land responses.

As a concluding remark to these (slightly) different definitions of desertification, Juntti and Wilson (2005) state that while it is clear that the difference in emphasis in the definition can lead to very different ways of conceptualising and diagnosing the problem and, consequently, to the adoption of different remediation techniques, different emphasis can also be used to serve different interests.

1.2.2. Land degradation

Many academic definitions of land degradation refer to a loss of the biological and/or economic resilience (see 1.2.4) and adaptive capacity[1] of the land system (Holling, 1986; Dean et al., 1995; Kasperson et al., 1995; Holling, 2001; IPCC, 2001). This approach emphasises the maintenance of basic system functions that may (or may not) include human uses. Building on this, it is argued that land degradation can only be determined in relation to the goals of the management system at the time of investigation (Abel and Blaikie, 1989; Turner and Benjamin, 1993), and in the context of a specific time frame, spatial scale, economy, environment and culture (Warren, 2002). In this context, Kasperson et al. (1995) define land degradation as “a decrease in the capacity of the environment as managed to meet its user demands”. This resonates with UN definitions emphasising the “resource potential” and “productive capacity” of the land (UNEP, 1992; UNEP, 1997). As such, the extent and severity of land degradation may vary between land users with different management goals in different places at different times and in different socio-economic, environmental and technological contexts.

Land degradation and environmental sustainability are mirror images of the same process (Warren and Agnew, 1988; Warren, 2002). Environmental sustainability depends on the inherent stability[2] and resilience (see 1.2.4) of the resources being used, their sensitivity[3] to change and the system’s capacity to adapt to change. For example, a *sustainable* land use system can either regain its productive potential after a perturbation (e.g. rapid and full recovery after drought) or provide alternative ways to support the livelihoods of those who depend on it (e.g. exploitation of bush encroachment by smallstock). By its definition, land degradation occurs when the resilience and adaptive capacity of the land is compromised.

Despite ongoing political and academic debate over the definition of land degradation, it is possible to distil a number of key components from this discussion. Land degradation: 1. is a human-induced phenomenon that cannot be caused by natural processes alone; 2. decreases the capacity of the land system as managed to meet its user demands; and 3. threatens the long-term biological and/or economic resilience and adaptive capacity of the ecosystem.

[1] The ability (often measured in the time it takes) for a system to regain the structure essential to support basic system functions after stress or perturbation (Kasperson *et al.*, 1995; IPCC, 2001)

[2] “The propensity of a system to attain an equilibrium condition of steady state or stable oscillation” (Holling, 1986: 296)

[3] The degree of system (or system component) change associated with a given degree of stress or perturbation

1.2.3. Drylands

The “arid, semi-arid and dry sub-humid areas” of the UNEP (1992) definition of desertification are collectively referred to as ‘susceptible drylands’ (UNEP, 1997; see Fig. 1.1). Hyperarid zones, the true deserts, are not included as they are not considered prone to desertification because of their naturally very low biological productivity.

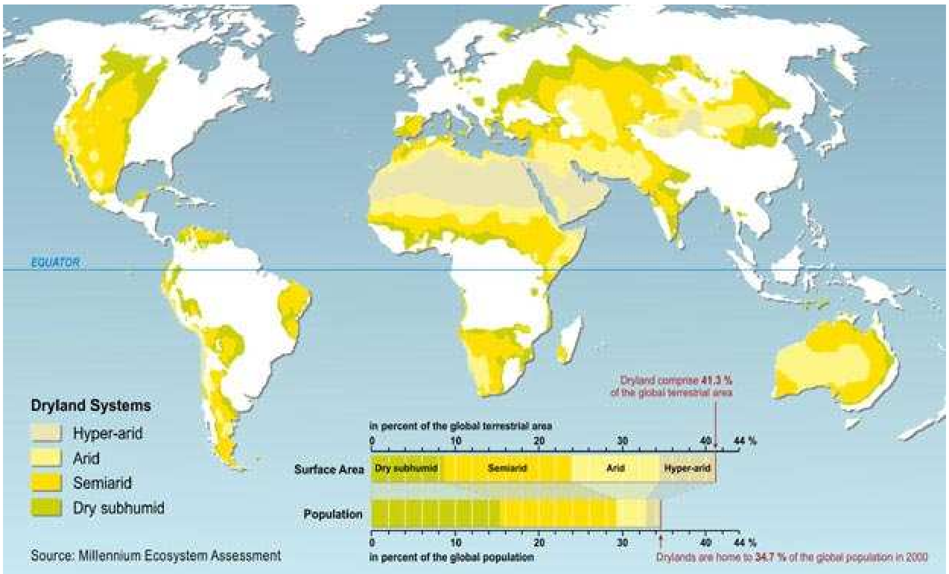


Fig. 1.1: Dryland systems. From: Millenium Ecosystem Assessment (2005).

1.2.4. Ecological dynamics: resilience, non-equilibrium and multiple-stable states

Currently, resilience is defined as the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks (Walker et al., 2004). The resilience perspective emerged from ecology in the 1960s and early 1970s (Folke, 2006). It was introduced by Holling (1973) as the capacity to persist within a domain in the face of change and as a measure of the ability of the system to absorb changes of state variables, driving variables and parameters and still persist. The useful measure of resilience was the amount of disturbance a system can take before its controls shift to another set of variables and relationships that dominate another stability region (Folke, 2006).

It is stated by Wiens (1984) that under natural conditions, disturbances are so frequent that there is rarely enough time between them for plant and animal communities to reach stable equilibria. It has been argued that ecosystems characterised by frequent disturbance, such as drought-prone semi-arid systems, therefore never reach equilibrium (e.g. Behnke et al., 1993; Scoones, 1995). Various authors have argued that for this reason, conceptions of equilibrium ecological dynamics are not relevant for semi-arid systems (e.g. de Angelis and Waterhouse, 1987; Ellis and Swift, 1988; Westoby et al., 1989). Such authors argue that these systems display “non-equilibrium” behaviour. For example, frequent droughts prevent livestock populations ever growing large enough to reach or exceed equilibrium with their fodder resources due to drought-induced mortality in cattle herds (Mace, 1991).

Alternatively, Gunderson and Holling’s (2002) framework captures equilibrium ecosystem dynamics within a broader framework of episodic ecosystem collapse and re-organisation. The concept views rangelands as complex systems capable of reaching stable equilibria, or ecological climax and yet vulnerable to collapse in response to perturbations (fire or a combination of grazing and drought in semi-arid rangelands) and able to re-organise to form potentially new species assemblages that become increasingly rich, connected and rigid as they build towards new equilibria (Gunderson and Holling, 2002; Walker and Abel, 2002).

1.3. Synthesis of previous and ongoing projects

In Appendix II a list of ongoing and past projects related to desertification is given. Many projects have been carried out, each with its own specialization, approach, expertise and specific objectives. Here, a synthesis of these projects is given that places them in a broader context. Classification has been carried out according to two criteria: type of project and their objectives (see Tables 1.1and 1.2).

In this comparative study, the two Tables 1.1 and 1.2 give an example of two ways to classify desertification related projects. In this way, an overview can be obtained from the overwhelming number of projects and they can be compared to each other without losing their identity as individual project with specific aims and foci.

1.3.1. Type of project and aim

Here, the type of project was chosen in the first instance, leading to databases, networks (e.g. to enhance collaboration and coordination in a certain field related to desertification), programmes (e.g. broad programmes that have several sub-projects) and projects. The latter are subdivided according to their aim or starting point:

- Projects that develop new technologies, methods or insight without using the results of previous projects. From analysis it has emerged that these kinds of projects are mainly past rather than present projects. As the number of projects and thus the results have increased, more recent projects usually start from the results of the projects of this category.
- Projects that start from previous projects' results and build on these to translate their results plus added insights and methods into useful tools and guidelines for end-users (e.g. policy makers).
- Projects that aim to compile information of a certain field. This information, usually from other related projects, exists but is inaccessible or scattered. These projects aim to compile this information and mostly also function as a discussion platform (thus related to the category 'networks').
- Projects that aim to improve the communication between involved parties in a certain field related to desertification.

Table 1.1: Desertification projects organized in categories regarding type of project and aim

Category: type of project / aim		**Project(s)**
Database		CORINE, DIS4ME, GLASOD
Network rather than project		ILTER, ROSELT, Desert*Net, DESERTSTOP, MEDCOASTLAND, MEDRAP, COST 634, (SCAPE), (WOCAT)
Programme rather than project		PAP/RAC, WWAP
Projects with aim to:	Develop new methods / insights / techniques largely without previous projects' results	PROTERRA, CAMELEO, CLIMED, DEMON-I, ECO-SLOPES, GEORANGE, ASMODE, JEFFARA, LUCC, MEDACTION, MEDALUS, MEDCHANGE, MWISED, PESERA, REDMED, TERON, VULCAN, (DESERTLINKS), Sustainable Uplands
	Start from previous projects' results and translate these into useful tools / measures / methods for end-users	DESURVEY, LADA, LUCINDA, SENSOR, DESERTWATCH, INDEX, LADAMER, MEDAFOR, REACTION, (WOCAT), (DESERTLINKS)
	Bring scattered, diffuse or inaccessible information together with or without new results	AID-CCD, ARIDnet, CLEMDES, (COST 634), (SCAPE) WOCAT
	Improve communication between involved parties	DISMED, WOCAT

As can be seen from Table 1.1, most projects reviewed here are projects which focus on developing new insights, technologies or methods while they use limited information from other projects. An example of a very large project is MEDALUS, which has had three phases. Later projects almost always refer to MEDALUS and use knowledge that is acquired in this project.
In Table 1.1, some projects are placed in brackets and appear in more than one category. In these cases, it was difficult to place the project under one heading. For instance, DESERTLINKS used information from earlier projects but also developed a new indicator system. Most projects do not belong strictly to one category. However, it was the objective of this synthesis to classify the projects, so they are placed in the category into which they fitted best. As has been said, this does not mean that projects of one category are the same as they all have their individual focus.

1.3.2. Objectives

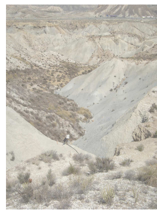
Another criterion by which to categorize the projects is their objective regarding the intention of how to deal with desertification. In Table 1.2, this criterion is used leading to the following categories:

- Policy-oriented, including management and decision making;
- Improvement of knowledge on e.g. the causes, status, mechanisms or impact of desertification;
- Practical activities or techniques;
- Identifying problems related to desertification;
- Identifying solutions
- (Use of) indicators
- Monitoring desertification, e.g. through remote sensing
- Other

Table 1.2: Desertification projects organized in categories regarding content of project

Category: objective	**Project(s)**
Policy or management oriented	COST 634, DESURVEY, ILTER, (LADA), LUCINDA, MEDCOASTLAND, SENSOR, (WOCAT), (WWAP), CORINE, DESERTWATCH, DISMED, GEORANGE, JEFFARA, (MEDACTION), MEDRAP, REACTION, SCAPE
Improvement of knowledge	(LADA), ROSELT, (WWAP), Desert*Net, LADAMER, LUCC, (MEDACTION), MEDAFOR, MEDALUS
Practical activities or techniques	PAP/RAC, PROTERRA, RECONDES, (WOCAT), ECO-SLOPES, MEDRATE, REDMED, TERON, Sustainable Uplands
Identifying problems	(AID-CCD), ARIDnet, (MEDCHANGE), VULCAN, GLASOD
Identifying solutions	WOCAT,
(Use of) indicators	(AID-CCD), DEMON-II, DESERTLINKS, INDEX
Monitoring desertification	ASMODE, CAMELEO, (DESURVEY), DEMON-I, (DEMON-II), DESERTSTOP
Other	CLEMDES, CLIMED, MWISED, PESERA

Almost all projects have as (part of) their objectives to improve sustainable development. As this is an overall objective of all projects, it is not taken into account in the classification. Apparent from Table 1.2 is that most projects are policy or management oriented. However, while many projects have sustainable management as their final objective, in their specific objectives they include several activities that relate to the final objective (e.g. the SENSOR project aims to develop tools to support decision-making). The activities in the second category (improvement of knowledge regarding the causes, status, mechanism and impact of desertification) range from developing, testing and applying methodologies for the investigation of impacts (MEDAFOR), to forming a binding link between the scientists who aim to investigate the complex causes and effects of desertification (Desert*Net). This example indicates the breadth of the categories and the diversity of projects that fall within one category. The third category includes projects that aim to deliver practical guidelines or new techniques, mostly in a specific field of desertification, e.g. the use of vegetation (RECONDES), or the development of methods to combine diverse stakeholder knowledge with cutting-edge science in Sustainable Uplands. The fourth category, identifying problems, is somewhat indistinct and includes projects that aim, for example, at assessing the vulnerability (VULCAN), the development and testing of a new desertification paradigm (ARIDnet). In the category of monitoring desertification, remote sensing and GIS play an important role (e.g. ASMODE, DEMON). The last category consists of projects that are too specific and could not be classified in one of the other categories. CLEMDES aims at the diffusion of information; CLIMED's objective is to provide information on climate change; GLASOD produced a global map of soil degradation; MWISED is focused on within-storm dynamics and the (erosive) effects; and PESERA developed, calibrated and validated a model to quantify soil erosion at the regional scale.



1.4. Key issues and outline

In this review, knowledge about desertification is compiled from literature and projects documentation. The concept of desertification encompasses a wide range of processes, other concepts, drivers, solutions and involves people with various backgrounds and interests (e.g. farmers, scientists, policy-makers etc.). These issues are not all fully understood yet, with all their (internal) feedbacks and interrelations. Therefore, it is impossible to give a complete review of desertification and its related issues. Some key issues that emerged from this review that should be kept in mind when assessing desertification are:

- Desertification is not a new phenomenon. From the many project dedicated to desertification problems, some dramatic headlines in newspapers (see above) it may seem that desertification affects all of the drylands and that if nothing is done soon, irreversible loss of ecosystem functions will occur, resulting in disaster. However, desertification is a natural phenomenon that occurred as a consequence of changing climate during e.g. the Pleistocene (see Chapter 2).
- The drivers of desertification are both human and natural. This key issue is assessed in Chapters 3 and 4 but reappears in everything related top desertification. The dry climate and short, intense rainstorms are an obvious cause of many desertification problems. However, the way man treats his environment (e.g. land use and policies) is an example of the human influence on desertification. In line with this view, we think that solutions to desertification problems should not only be sought in biophysically oriented approaches, but also that policies and local land users should be involved in finding solutions.

Outline

In Chapter 1 an introduction is given to the subject of desertification, the aims of this review are stated and definitions of some key concepts are given. A synthesis is given of projects that assess or have assessed desertification in terms of aims, type of project and objectives.

Chapter 2 gives a brief overview of the history and evolution of desertification in the Mediterranean. With this, desertification can be placed in an historical context which adds to the understanding of the problem.

In Chapter 3 the primary drivers of desertification are discussed in a general way first, which shows the many interactions, feedbacks and interrelations of the problem. Two case studies are described as examples and a synthesis is given of the perceived causes of the problems in de DESIRE hotspots.

Chapter 4 deals with processes and consequences of desertification, split up in socio-economic factors and biophysical processes. An emerging conclusion is that the problems of

desertification are more of a biophysical nature, while their causes can be both biophysical and socio-economic or political (see section 4.3).
In Chapter 5 indicators of desertification are discussed and techniques to monitor or measure these.
In Chapter 6 various types of models which simulate desertification related issues, from large climate models (GCMs) to vegetation and hydrological models. These are models that reflect the biophysical environment. In section 6.4, socio-economic and participatory modelling is discussed.
Finally in Chapter 7 solutions to the desertification problem are discussed, again divided in biophysical and socio-economic solutions.
Some extra information is given in two separate appendices: Appendix 1 gives extensive information on the DESIRE project, its geographical context and the DESIRE study sites. In Appendix 2 a brief, standardized description of 48 ongoing and past desertification related projects is given.

Chapter 2
Evolution of desertification in the Mediterranean

2. Evolution of desertification in the Mediterranean

To understand the origin and evolution of desertification, a brief summary of past environmental changes and processes in the Mediterranean is given. By looking at past desertification, the full length of timescales over which land degradation occurs can be defined and, as a consequence, the notion of reversibility of degradation can be put into a better long-term context (Wainwright, 2004).

The history of desertification in the Mediterranean follows the course of evolution of two groups of causes, i.e. natural and anthropogenic, and their interactions (Sciortino, 2001). Natural events acting on the environment were dominant until ~5000 BC, after which human influence increased until the present (Grove, 1996; Quézel, 1999). Important is, as Puigdefábregas and Mendizabal (1998) underline, that desertification as an outcome of climatic and social driving forces operating synergetically is not a new phenomenon in the Mediterranean region.

2.1. Climatic fluctuation

During the successive glaciations of the Pleistocene, the Mediterranean region was covered by open low biomass producing steppe-like vegetation. This was associated with unstable landscapes and low rates of soil development, erosion and formation of colluvial deposits and large alluvial fans during the middle Pleistocene (Sciortino, 2001). The advance of forests during the temperate interglacials, interrupted these periods of land instability. During the last glaciation prior to its maximum (~30,000 – 25,000 years ago), pollen evidence shows that much of southern Europe was covered by *Artemisia* steppe interspersed by patches of forests and scattered stands of trees (Grove, 1996). In the eastern Mediterranean shoreland a change in the sedimentation regime took place around 14,000 BP: instead of calcareous arenite, a red soil was being formed, indicating an increase in humidity. The area became rich in vegetation and aeolian dust was deposited (Dan and Yaalon, 1971). During the final cool period of the Younger Dryas (c. 12,900 – 11,500 years ago), precipitation was much lower than at present and wind-borne silt from the Sahara was widely deposited while vegetation was of forest-steppe type (Grove, 1996).

Allen (2003) describes a ‘route’ of vegetation change in the early Holocene, which started in southern Spain and gradually moved northwards (Gulf of Lion). Evidence from southwestern Turkey (Eastwood et al., 1999), Greece and the Balkans suggest that the mountains acted as glacial refugia from where early expansion of deciduous taxa would have occurred (Allen, 2003). The Climatic Optimum (8000 – 6000 years BP) had a more extensive forest cover and a warmer and moister climate than since the Last Interglacial and was an important period for pedogenesis around the Mediterranean (Grove, 1996). Evidence for an eastern trend in vegetation development is recognized by several authors (e.g. Horowitz, 1975; Gat and Magaritz, 1980; Grove, 1996 and Allen, 2003). Fluctuations in climate were at intervals repeated from around 5000 BP until the Little Ice Age (~1550 – 1850 AD), involving vertical movements of the snow- and tree-line through a few hundred metres (Grove, 1996). Such oscillations, however, are likely to have played a less important role in the modification of the Mediterranean ecosystems than variations in human activity (Grove, 1996).

2.2. Human influence

Human impact on Mediterranean landscape modification occurred very early. The first hominid site in the Levant was dated at 1.4 million years ago (Conacher and Sala, 1998). The impact of people through hunting and food gathering was, however, insignificant. The use of fire initiates another phase of human impact around 400,000 BP. Since the Neolithic Age (7000 – 4000 years BC), human actions started to having marked effects on European natural ecosystems, becoming prominent during the Bronze Age (Sciortino, 2001). In the former, the beginning of agriculture and pastoral livestock husbandry is considered to have been a major revolution in human technological development (Conacher and Sala, 1998). The Mediterranean areas in Israel, Lebanon, Syria and Turkey were probably the first sites of domestication and cereal cultivation. In the lowlands, extensive clearing by fire and the introduction of the plough led to increased rates of soil erosion (Conacher and Sala, 1998). This corresponds with indications of forest degradation around 6500 BP in southern France and eastern Spain (Vernet and Thiébault, 1987). A time lag of about 1000 years between the beginning of the Neolithic and its consequences in forest degradation is observed by these authors. Another phase of cultivation started around 5000 BP with, according to Conacher and Sala (1998), the domestication of fruit trees and lasted until the end of the Roman period in the 7th century AD. Land clearance was extensive, affecting the mountainous areas. Terraces were built to minimize erosion and gain agricultural land, soil and water conservation methods were applied and the population grew to the highest numbers in historical time until the present. Roman imperialism caused extensive pressure on Mediterranean resources. Growth of cities and of the large rural and urban populations and extensive engineering works all contributed to increasing pressure on Mediterranean ecosystems. In the 6th century AD populations decreased, partly as a consequence of conflict between Roman and northern peoples and partly as a result of disease such as the Great Plague of 542 AD (Hodges and Whitehouse, 1983, in Grove, 1996). Trade between east and west diminished, rural estates and towns were abandoned and hydraulic works fell into disrepair (Grove, 1996).

In the eastern Mediterranean, the fifth phase of human influence (Conacher and Sala, 1998), started with the Muslim conquest of the region and the decline of its economy and agriculture. Pastoral nomadism replaced irrigated hill lands and irrigation ditches. The geomorphic effect was increased erosion, loss of soil in the uplands and the creation of swamps in the lowlands due to river siltation (Conacher and Sala, 1998). The Black Death of the mid-14th century emptied the Mediterranean countryside and a renewed plague in 1376 killed half the remaining people (Grove, 1996). In the course of the 16th century, climatic fluctuations caused harvests to diminish in some years. These mark the onset of the Little Ice Age, characterized as a cooler and more humid though highly variable climatic period (Puigdefábregas and Mendizabal, 1998), with its maximum in the second half of the 17th century being around 0.5°C colder than at present. This coincided with social changes, such as religious wars, recurrent famines and plague, resulting in extensive land use changes. An example from Spain where land use changes in the 16th and 17th century occurred as a result of the establishment of Christian rule and colonization in America. This caused a southwards expansion of the dryland agriculture that prevailed on the inner Iberian high plains and a high demand for wool and wood products to meet the needs of American settlers (Puigdefábregas and Mendizabal, 1998). The land use changes led to increased erosion, shown by sedimentological, archaeological and ecological evidence (Puigdefábregas and Mendizabal, 1998). The consequences are, among others, increased sedimentation rates, higher flood frequencies and the conversion of forest to grassland in the subalpine belts. This latter conversion caused a downward extension of the solifluction limit with an increase in mudflows and a possible doubling of specific runoff and an increase by 16 times of specific sediment yield (Puigdefábregas and Mendizabal, 1998). In the late 17th and early 18th century signs of land shortage, overgrazing, deforestation and erosion became apparent in the rural areas of southern France, northern Italy and Sicily (Grove, 1996). Recent historical changes in the Mediterranean differ between countries. In southern Spain and Portugal, population was sparse due to continued war between the two countries; deforestation as a result of charcoal burning occurred and soils were barren. Crete seems to have been reasonably prosperous in the 18th century, trading in olive oil and wine (Grove, 1996). Population declined as a result of plague and the Greek War of Independence (1821-28) against Turkey (Grove, 1996) and terraces were probably abandoned during these times. In France, unlike the countries mentioned so far, population increased from 1730 to 1850 by 50% (Price, 1981 in Grove, 1996). The nobles had retained their land and woods, smallholdings were subdivided, marginal lands were cultivated and people depended on their common rights in the forests

(Grove, 1996). In the mid-19th century, arable land declined and populations in the cities grew at the expense of rural communities. In Spain, overpopulation in rural areas is associated with the encroachment of agriculture on rangelands and the increase of stock densities, which was followed by grassland exhaustion and soil loss by erosion (Puigdefábregas and Mendizabal, 1998). In Conacher and Mala (1998), the sixth phase of human influence on the environment consists of the last 100 years, called the technological phase including changes such as land reclamation, monoculture in agriculture and forestry, introduction of exotic plants and animals, mechanization and the use of pesticides and fertilizers. According to these authors, impacts on the environment differed between developed and under-developed regions. In the first, industrialization accelerated and the number of grazing animals declined, reservation of protected areas increased and reforestation occurred. In developing countries, on the other hand, large population growth increased the pressure on natural areas, causing vegetation decrease. According to Coccossis (1991), migration in the 1950s and 1960s was generally out of disadvantaged areas (islands, mountainous areas) and from rural to urban centres. As a result, marginal areas were abandoned, leading to increased erosion. Agricultural production increased due to mechanization and irrigation, intensifying agriculture in some areas but at the same time increasing pressure on local resources (Coccossis, 1991). One of the most important contributors to economic growth in the Mediterranean area, however, was tourism, which increased by 150% in a decade. Additionally, urbanization and growing tourism increased the pressure on coastal areas, where this activity is concentrated.

Chapter 3
Primary drivers of desertification

3. Primary drivers of desertification

The causes of dryland degradation are widely discussed in the literature but remain controversial (Thomas, 1997; Lambin et al., 2001; Reynolds and Stafford Smith, 2002; Geist and Lambin, 2004). Apart from papers trying to reach a consensus on the driving factors and feedbacks leading to desertification, many case studies exist in the literature that investigate the causes and processes of dryland degradation in specific areas (Geist and Lambin, 2004). It is not the scope of this review to enumerate all the primary factors or drivers of desertification that have been defined by scientists, or to define these drivers precisely and try to define a comprehensive list, that includes some but excludes others. Primary factors driving the desertification process in the Mediterranean area specifically are mentioned and discussed in this chapter.

First of all it is important to recognize that dryland ecosystems are inherently non-equilibrium systems and ecosystem dynamics are essentially event-triggered (Puigdefábregas, 1998). Most disturbances, such as rainfall variability and fire, are incorporated in dryland ecosystems during their evolution. However, some disturbances are new or not yet incorporated and may drive the system to qualitatively different new states along irreversible trajectories (Puigdefábregas, 1998).

3.1. Biophysical and socio-economic causes

There is a great deal of debate amongst scientists as to whether the causes of desertification should be sought in the socio-economic or the biophysical sphere, and on the degree to which these causes are local or remote and how variables interact across organizational levels in different regions in the world and during different time periods (Lambin et al., 2002; Reynolds and Stafford Smith, 2002; Geist and Lambin, 2004). However, most authors (e.g. Turner et al., 1995; Puigdefábregas, 1998; Geist and Lambin, 2004) agree that there is not one single factor that causes desertification or land degradation. Both biophysical and socio-economic factors should be considered, even jointly, as they interact and reinforce each other to induce transition trigger events (Turner et al, 1995; Puigdefábregas, 1998). Related to this is the issue that it is often difficult or even impossible to separate natural from human-induced degradation. In many cases, climate or climatic change acts as a boundary condition, but without human actions this would not necessarily lead to degradation. Disturbances, connected with transition triggers and due to change in, for example, climate, soil, social, cultural and economic factors, can drive environments prone to drought and exploited by humans to desertification. The disturbances, then, are such that boundary conditions are changed and the system is overexploited (i.e. it is driven beyond its resilience thresholds) (Puigdefábregas, 1998). This latter notion, however, suggests that any ecosystem, prone to desertification was in a state of equilibrium in the past (i.e. before the disturbances). However, there are also models of non-equilibrium that argue that there may in fact be multiple equilibrium points (Hutchinson et al., 2005). This is a separate, though interesting discussion point not central to this review. The reader is referred to papers such as Folke (2006) and references therein.

In the literature, many processes are named that contribute to desertification: from overgrazing and improper management of irrigation, to political pressure, urbanization and climatic hazards. In two studies (Turner et al., 1995 and Geist and Lambin, 2004), the causes of land use/cover change and desertification are discussed in a general way. They illustrate the complexity and interrelationships of drivers of desertification. Both studies recognize both biophysical and socio-economic causes. Geist and Lambin (2004) combine biophysical and social drivers in their 'underlying driving forces' (see Fig. 3.1).

In many studies (e.g. UNEP, 1997; Lambin et al., 2001) the view that one factor, such as population or poverty acts as the underlying cause of land degradation is rejected. Geist and Lambin (2004) analyzed 132 subnational case studies on the causes of dryland degradation to determine whether the proximate causes (human activities of immediate actions at the local level, e.g. cropland extension) and underlying driving forces (fundamental social and biophysical processes, e.g. agricultural policies or human population dynamics (see Fig. 3.1)) fall into any pattern and to identify mediating factors and feedback mechanisms that may lead to typical pathways of dryland degradation. They suggest multiplicity as the most common theme reported in the case studies they analysed. The complexity is accounted for by system dynamics, according to the authors, with special emphasis on the initial conditions and adaptation of the system, the heterogeneity of the actors, the hierarchical levels of organisation and the non-linear dynamics caused by feedback mechanisms. Above this the complexity is associated with a limited number of typical pathways that lead to desertification (Geist and Lambin, 2004; see section 3.2).

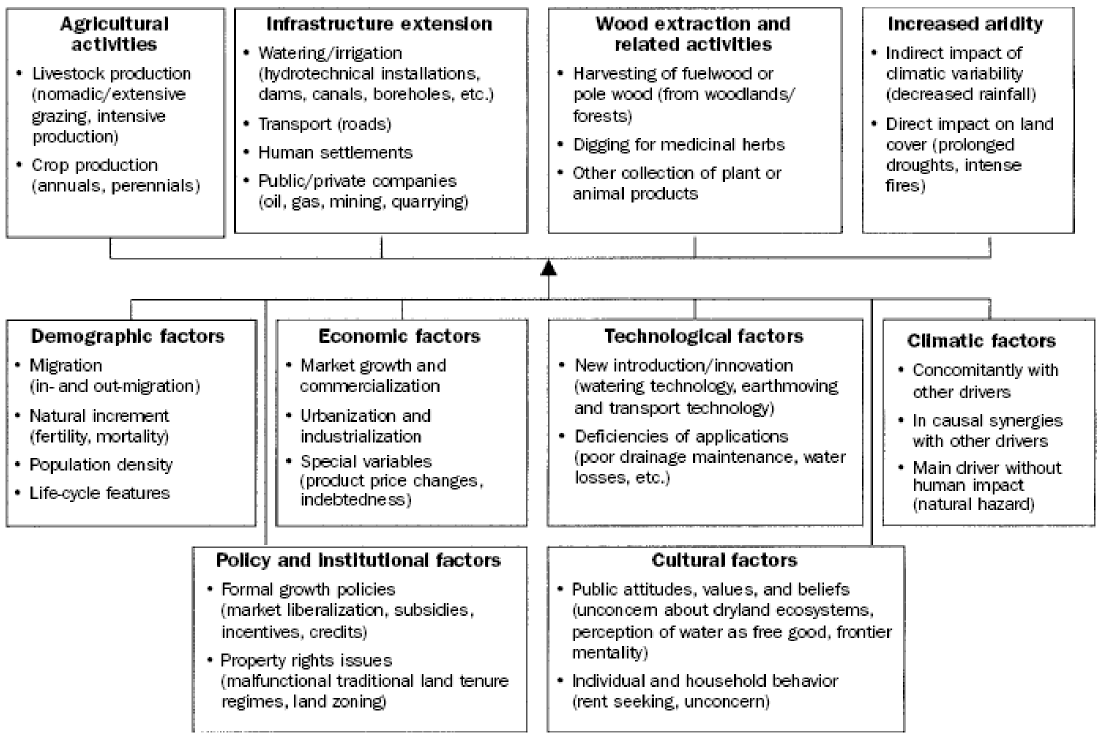


Fig. 3.1: Causes of desertification: six clusters of underlying driving forces underpinning the proximate causes of desertification (from: Geist and Lambin, 2004; Geist, 2005).

Turner et al. (1995) focus on land use and land cover change. The driving forces recognized by them, however, are applicable to the desertification issue as well, as change in land use/cover may lead to degradation and desertification. They state that the relative dynamics of interacting forces should be recognized, as variables appearing as drivers at one scale, may seem constant at another. Over and above this, feedback effects are possible at another scale than the driving force (Turner et al., 1995). For example, the aggregate effect of groundwater withdrawal from individual wells may be a general desiccation of the landscape.

Turner et al. recognize three dimensions of drivers relevant to land use/cover change (See Fig. 3.2): socio-economic, biophysical and land management (proximate causes), which then can be put in cultural and historical context at various scales.

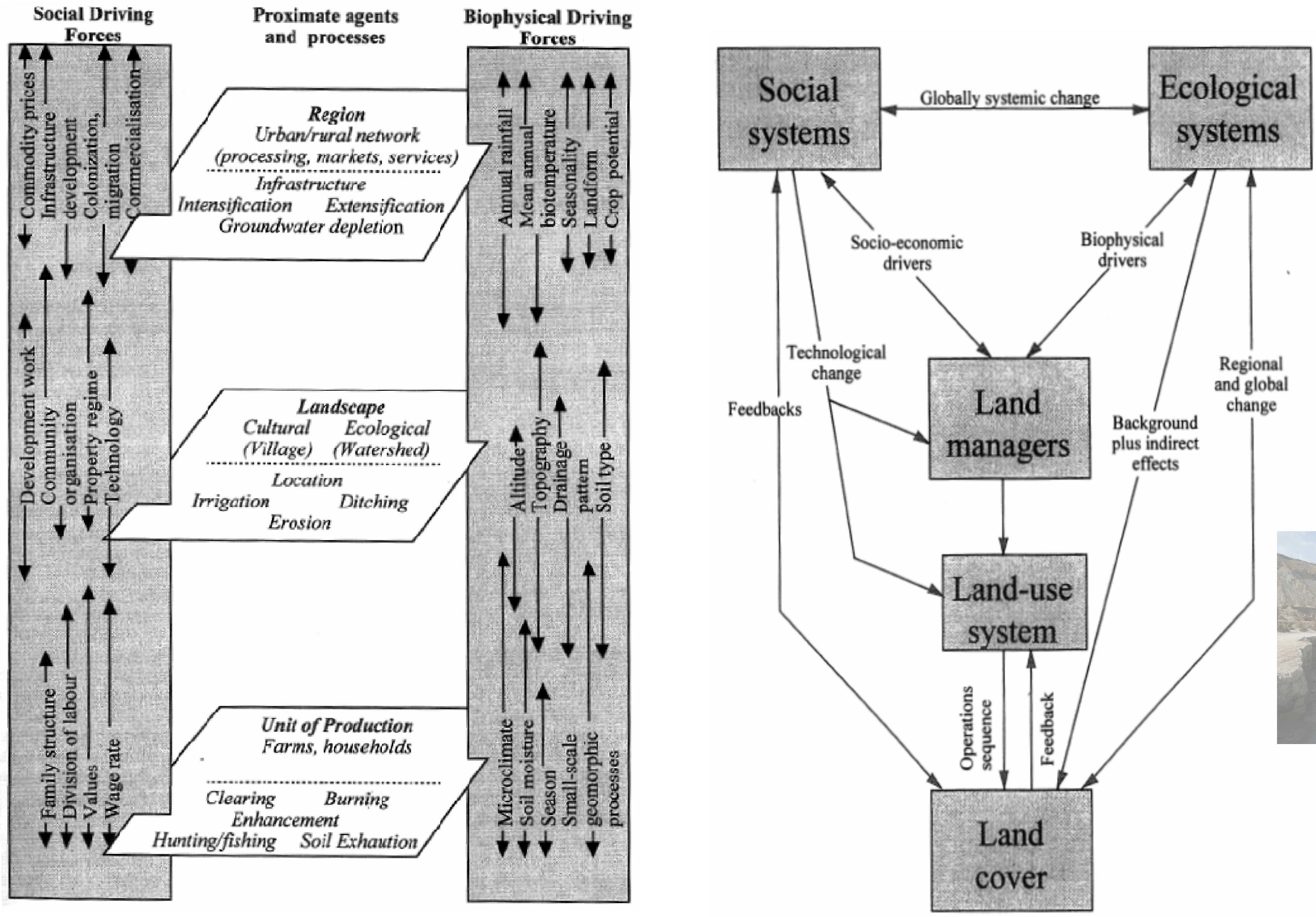


Fig. 3.2: Multi-scale driving forces in land use/cover change (left); and framework for understanding land cover changes (right) (from: Turner et al., 1995).

3.2. Pathways of desertification

Lambin et al., in 2001, conclude that various human-environment conditions react to and reshape the impacts of drivers differently, leading to specific pathways of land-use change. Geist and Lambin (2004) underline this for the process of desertification: ‘Dominant causative factors and feedbacks, combined with environmental and land-use histories, allow the identification of typical regional pathways of desertification.’. The typical pathways they identified for Africa and Europe are discussed here. This first involves the spatial concentration of pastoralists, resulting from a shift from a nomadic to a sedentary way of life, with farmers living around infrastructure nuclei. This results in overgrazing, extensive fuelwood collection and high cropping intensities, ultimately leading to degraded vegetation and declining soil productivity during periods of drought (Geist and Lambin, 2004). A common trajectory of dryland change in the Mediterranean basin of southern Europe involves the millennia-old tradition of agro-pastoral land use, which removed nearly all forest cover, favouring an highly resilient phrygana (shrub) vegetation, reflecting various stages of soil degradation. Risks are evident when mechanization of farming on skeletal soils induce further soil erosion or when grazing on remote mountain ranges is followed by devastating fires (Geist and Lambin, 2004).

In Lambin et al. (2001), pathways or conditions that appeared repeatedly in the case studies reviewed include: weak state economies in forest frontiers; institutions in transition or absent in developing regions; induced innovation and intensification, especially in peri-urban and market accessible areas of developing regions; urbanized aspirations and income with differential rural impacts; new economic opportunities linked to new market outlets; changes in economic policies or capital investments and inappropriate intervention giving rise to rapid modifications of landscapes and ecosystems.

3.3. Driving Forces in the Mediterranean

According to the UNCCD and the countries themselves, the Mediterranean countries of Portugal, Spain, Italy, Greece and Turkey have a marked problem of desertification because of the occurrence of particular conditions over large areas (UN, 1994). These conditions include:

- semi-arid climatic conditions affecting large areas; seasonal droughts; high rainfall variability and sudden and high-intensity rainfall; poor and highly erodible soils prone to develop surface crusts;
- uneven relief with steep slopes and diversified landscapes;
- extensive forest losses due to frequent wild and anthropogenic fires;
- crisis conditions in traditional agriculture with associated land abandonment and deterioration of traditional soil and water conservation measures;
- unsustainable exploitation of water resources leading to serious environmental damage, including chemical pollution, salinization and exhaustion of aquifers; and
- concentration of economic activity in coastal areas as a result of urban growth, industrial activities, tourism and irrigated agriculture.
- Political decisions regarding e.g. subsidy on certain crops of infrastructure.

In northern Africa, the causes of land degradation can be grouped, according to Conacher and Sala (1998) into:

- loss of plant cover and increased erosion,
- lithology and pedology,
- rainfall concentration and intensity;
- demographic explosion and
- human factors and social aspects.

Two case studies from the Mediterranean, one in Sardinia and one in Tunisia, are described briefly to illustrate the causes of desertification in more detail in the area of interest of this literature review.

3.3.1. Example case study 1: Sardinia (Enne et al., 2002)

Sardinia is one of Italy's regions most threatened by land degradation, with unproductive lands representing about 12% of the total area (excluding urban and coastal areas and inland waters). About 85% of the Sardinian land is currently used for agriculture, with livestock farming being one of the main economic activities. This results in intensively grazed meadows and pastures and both wooded areas and arable land are cultivated to provide forage and other animal feeding sources.

In order to evaluate the effect of agro-pastoral activities on land degradation, a case study in Sardinia was carried out under the auspices of the MEDALUS II project. Animal behaviour was studied and the effects of stock trampling on soils were determined. From the latter is it was concluded that winter is the season during which the risk of soil degradation due to trampling is highest, as soil moisture values are highest then. The effect of continuous high stocking rates was compared to ungrazed areas (marginal areas with low productive potential due to steep slopes, stoniness and limited soil depth). The use of high and continuous stocking rates caused an increase in the area of bare soil surface, leading to increased soil erosion risk. Comparisons between a ploughed-cereal area and a natural *Maquis* area showed that the latter maintained soil losses far below the critical level in autumn. The intensification of cropping on hillslopes increased erosion risk, particularly if crop establishment was slow and ploughing was done across contours instead of parallel to them. The authors conclude that practices related to agro-pastoral activities, such as overgrazing, badly planned cultivation and the use of fire to clear pastures, can be considered the main causes of desertification.

3.3.2. Example case study 2: Tunisia (Mtimet et al., 2002)

Tunisia has extensive arid zones (see Fig. 3.3) that are extremely sensitive to various forms of land degradation and a number of development programmes and studies to combat desertification are executed in the country. Arid bioclimates cover over 63,000 km^2, of which 11.8 % has been assessed to be very degraded, 36.6% to be moderately degraded and 17% to be slightly degraded (Mtimet et al., 2002). There has been no significant climatic changes since the end of the last century, so the authors state that the present signs of desertification cannot be attributed to an increasing dryness of the climate. Instead, they are caused by human and animal pressure on fragile ecosystems. The stresses are listed as follows:

- inappropriate use of soils, through extending arboriculture and cereal crops into zones that should be used as rangelands only;
- use of inappropriate equipment for the preparation of soils (e.g. the use of polydisc ploughs in sandy soils sensitive to wind erosion);
- increasing numbers of livestock in conjunction with a decrease in the area of rangeland, resulting in overgrazing, a deterioration of soils and a decrease in plant species suitable for grazing;
- removal of wood for domestic use, which is one of the main causes of the decline of tree and shrub species;
- use of high salinity water for irrigation, contributing to the salinization of soils and the decline of their fertility; and
- urbanization, particularly in coastal areas and around ancient cities and towns, resulting in land, often the most fertile areas, taken out of production.

These pressures work as causes of degradation, as their effects include water and wind erosion, deterioration of the vegetation cover, and degradation due to hydromorphy and salinization.

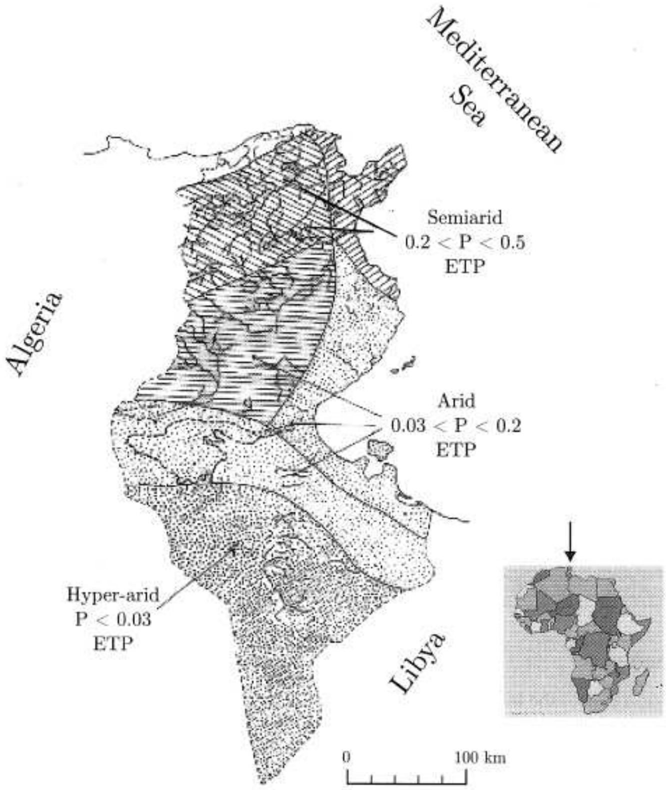


Fig. 3.3: Bioclimatic map of Tunisia (from: Mtimet et al., 2002)

3.4. Synthesis of causes for DESIRE hotspots

Since this literature review is a starting point for the DESIRE project (see Appendix I), the problems occurring in the DESIRE hotspots were analyzed regarding their causal agents. Here an overview and synthesis is given of the various problems and the factors that are perceived to be primary causes of these problems. See Chapter 4 for a more detailed description of the various desertification related problems.

In Table 3.3, all DESIRE hotspots are listed in the rows, while the perceived desertification related problems are given in the columns. If the problem is perceived but no particular reason or cause is given, this is indicated by an ‘x’. If a possible cause is given for the particular problem, this is indicated with a letter, of which the explanation is given below the table (a – q). Importantly, in all hotspots the major reason for the problem included the climate. Most importantly the long period of drought and the torrential and irregular nature of rainfall were named. However, as the climate is inherent to the Mediterranean area and to desertification, and it cannot be mitigated by any realistic measure, this factor is left out of this analysis.

As can be seen from Table 3.3, causative factors differ between hotspots even if the same desertification problem is experienced, which is due to specific circumstances for each area. In total, apart from the cases where the cause is ‘not specified’, the two causes mentioned most often are inadequate agricultural or forestry practices and clearance of vegetation for agriculture. As not all causes are specified, research should be carried out as to what might cause the perceived problem. Once the underlying cause of the problem is known, it is easier to identify and provide a solution.

For water erosion, many factors are perceived to be causative. The most often named groups of causes are inappropriate or inadequate agricultural or forestry practices, followed by rock or sediment type. As with climate, the latter is problematic to overcome, though with adequate agricultural practices focusing on the weak soil substrate, problems might be decreased. For land use changes, the (past) clearance of natural vegetation for agricultural purposes is usually the main cause, except for the situation in Portugal where migration led to the abandonment of fields and thus to land use change. The overexploitation of water sources is almost always due to a competition between users.

Often, one desertification problem leads to another. Water erosion and urbanization upstream can be the cause of flooding and siltation of lower lying areas. Land use change leads to problems such as forest fire, water and wind erosion, overgazing etc.

3.5. Conclusions

From the two case studies of Tunisia and Sardinia that review causes of desertification in a general way, it is clear that both biophysical as well as socio-economic factors need to be considered. These studies and the overview of DESIRE hotspots confirm this, with both urbanization (entirely socio-economic) and livestock management and salinization (incorporating a biophysical dimension). Also, multiplicity seems to be a recurrent theme in both the general reviews and the case studies presented here. A slight difference between the two types of studies can be seen in the role of climatic change. In the overviews, climatic change is an underlying factor that may play a role in determining the extent of degradation. In both case studies, however, climatic change is not considered important for the (recent) desertification problems. This may be due to the scale that the researchers are considering: at the local spatial and short-term temporal scale, climatic changes may not seem to be important or change is even not noticed. However, when reviewing several cases at, probably, larger temporal and spatial scales, climatic change can become an important underlying force of land degradation and desertification.

Table 3.3: Synthesis of the desertification problems for each DESIRE hotspot, including perceived possible causal factor of each problem

DESIRE hotspot		*Desertification related problem*									
country	*location*	water erosion	wind erosion	salinization	forest fire	vegetation degradation	land use changes	overgrazing	overexploitation of (ground)water	flooding	urbanization
Spain	Guadalentin Basin	a,b,c		x							
Portugal	Mação	d,e			x	e	b				
Italy	Rendina Basin	c,d,e,f			x						
Greece	Crete	a,b,h,i		g		e,i	h	x	j	x	
Greece	Nestos Basin			g,j,k,l							
Turkey	Konya Karapinar Plain		d								
Turkey	Eskisehir Plain	m									
Morocco	Mamora/Sehoul	d	c			i,n			d,j		x
Tunisia	Zeuss-Koutine watershed	x	x	x		o	h	o	j		
Russia	Djanybek			x		x					
Russia	Novij, Saratov			d							
China	Loess Plateau	c,d,h,i,m				d,h,i	h	x			
Botswana	Boteti area		x			x		x			
Mexico	Cointzio catchment	c,f,i,o,				c	h	o			x
USA	Walnut Gulch watershed	x					x			p	x
Australia	Glenelg Hopkins region			h			h		j		
Chile	Secano Interior region	c,d				h,q	x	x		p	
Cape Verde	Santiago Island	d								x	

Perceived causal factors:

a. (frequent) tillage
b. land abandonment, migration
c. rock / sediment type
d. inadequate agricultural or forestry practice
e. forest fire
f. deforestation
g. poor soil drainage
h. clearance of vegetation for agriculture
i. overgrazing
j. increasing demands from irrigation and/or human consumption
k. flood-control works
l. sea-water intrusion
m. lack of natural vegetation cover
n. forest disease
o. transition from extensive to intensive livestock husbandry
p. upstream erosion
q. past overexploitation of the soil
x. not specified

Chapter 4
Processes and consequences of desertification in the Mediterranean

4. Processes and consequences of desertification in the Mediterranean

In Chapter 3, the underlying causes of, and processes leading to, desertification are discussed. In this chapter, the processes and consequent problems of desertification are discussed. As the concept of desertification (see 1.2.1) is very broad, many environmental problems can be attributed to desertification (Martinez-Fernandez and Esteve, 2005). Here, we focus on the problems experienced in the Mediterranean area. However, they will be described in a general way. As knowledge of most problems is extensive, we refer to relevant papers rather than repeating them here. This chapter is divided in two parts: biophysical and socio-economic processes. However, it is not always possible to strictly divide problems in these categories, as interactions and feedback play a role. Examples include overgrazing and competition for water resources, so the division should not be seen as strict, but rather as a way of structuring occurring problems. Also, as Conacher and Sala (1998) rightly state, a particular desertification problem does not exist on its own, which often makes it difficult to isolate the most serious problems. This is why in this chapter, both processes and consequences are discussed.

4.1. Socio-economic and political factors

Although there are socio-economic and political causes and consequences of desertification, this chapter focuses on how these factors influence desertification processes.

4.1.1. Urbanization

The consequences of increased urbanization in Mediterranean countries may lead to degradation or even trigger desertification. There is a number of problems due to urbanization. First, an increase in the consumption of (often prime) land that is poorly planned and regulated so that settlement may occur in increasingly marginal locations, for example, on steep slopes which may be vulnerable to landsliding (Wainwright and Thornes, 2004). Also, due to urbanization agricultural use of areas is pushed to marginal land, raising problems there. Second, water supply comes under increasing pressure and drainage and removal of waste water and sewage become increasingly difficult. Third, issues of the production of solid waste are important and air pollution increases. Also, an increase in impervious surfaces leads to an increased risk of flooding, especially when expansion of the urban area includes mountainous terrain and aquifers may become depleted as a result of overexploitation (Conacher and Sala, 1998).

4.1.2. Competition for scarce water and unsustainable water management

Drought and shortage of water are an inherent part of the Mediterranean type of climate and of the desertification problem. The areas that experience this type of climate have a dry season in which soils and vegetation become water-stressed. Subsequently, most of the available precipitation typically falls in torrential storms, leading to problems such as water erosion and flooding, which may be exacerbated by drought-enhanced soil water repellency. All problems related to desertification as described in this chapter (e.g. wind erosion, salinization etc) can eventually be traced back to water related problems, so they could all be categorized under this heading. These problems, however, are experienced as such by the local people. Under the heading ‘water related problems’, problems directly related to water are discussed including flooding and the competition for scarce water sources. Overexploitation of the scarce water resources by e.g. bad management or agricultural practices is often a problem. Increasing tourism and urbanization also add to this competition.

Competition for scarce water resources is a problem in many areas susceptible to desertification that is likely to be compounded by climate change in many drylands. According to Stern (2006), over 1 billion people will suffer water shortages as a consequence of climate change by 2100. In addition to increased demand for irrigation under future climate change, water shortages may be further compounded by increasing tourism, urbanization or industrialisation. Changes in agricultural practices, such as transitions from nomadic to settled agriculture and technological advances that facilitate year-round irrigation, aggravate the problem. Increased water demand from the agricultural, industrial and domestic sectors in many dryland countries has led to ground-water extraction far in excess of recharge rates, leading to fears about the long-term viabililty of these systems. In areas adjacent to salt-water aquifers, over-extraction of ground water can lead to aquifer and soil salinization (this is often a particular problem in coastal areas). Where aquifers cover wide areas, and particularly where water is supplied by rivers that cross international boundaries, competition for water becomes an international political issue. For example, there is predicted to be a 75% drop in Nile waters that supply water to ten countries by 2100 (Stern, 2006). At a local level, there are numerous examples of grassroots institutions that successfully manage access to water between groups of farmers, but such co-operation will increasingly need to take place at a national and international scale.

4.1.3. Abandonment

In contrast to the trend of cultivating more marginal lands in some countries, there is a distinct trend of the abandonment of formerly cultivated marginal lands in the EU Mediterranean countries. The effects of this process are difficult to predict, as the abandoned fields show different evolutions depending on various environmental and land-use features (Kosmas et al., 2002). On the one hand, degradation may decrease when cultivation techniques (e.g. ploughing, leading to erosion) have ceased and natural vegetation takes over. On the other hand there is a risk of further degradation when cultivation structures (e.g. terraces) collapse and when (over)grazing is allowed on the abandoned lands. However, land abandonment is not a recent or new phenomenon (Thornes, 2002); it occurred throughout (early) history in the Mediterranean basin.

4.1.4. Policies

Many land use changes are the direct or indirect effect of local, regional, national or EU policies. An example of the latter is the subsidy farmers get for cultivation of certain crops, e.g. almonds or olives in SE Spain. Without these subsidies, land use would probably be different. Processes such as urban migration and consequent rural depopulation and irrigated agriculture expansion form the social dynamics of desertification and have more often than not been supported, if not initiated, by governmental intervention (Oñate et al., 2005). Wilson and Juntti (2005) explore the policy-related factors and processes that have contributed to desertification.

4.2. Biophysical processes

4.2.1. Erosion

Erosion is a natural phenomenon occurring over much of the Earth’s surface, but its extent and intensity have been greatly increased by human activities (UNEP, 1997). It is the detachment, entrainment and transport (and deposition) of soil particles caused by one or more natural or anthropogenic erosive forces (rain, runoff, wind, gravity, tillage, land levelling and crop harvesting) (Boardman and Poesen, 2006). Erosion is subdivided in two main processes: water erosion and wind erosion. Erosion directly affects the area where the process occurs but may also have negative off-site effects in areas that receive the eroded material such as reservoir sedimentation or through dust storms that can travel hundreds of kilometres from their source area (UNEP, 1997). Erosion embraces a complex set of processes and interacting factors. Whether or not erosion takes place, and with what intensity, depends on the balance between erosivity and erodibility. The former variable is the potential ability of rain or wind to cause erosion and it is controlled by factors such as wind strength and rainfall intensity. Erodibility is the vulnerability of the soil to erosion, influenced by physical soil characteristics, land use and management techniques. There are many case studies of soil erosion. A useful textbook is by Morgan (2005). An extensive review of erosion in Europe is given by Boardman and Poesen (2006).

4.2.2. Salinization

Salinization is the concentration of salts in the surface or near-surface zones of the soil and is a major process of land degradation (Thomas and Middleton, 1993) It is a natural process resulting from high levels of salt in the soil, originating from landscape features that allow salts to become mobile (movement of the water table) and from climatic trends in favour of salt accumulation. Alternatively, it may occur resulting from management practices (USDA, 1998). The latter, human-induced, salinization is often referred to as 'secondary salinization' to distinguish it from naturally affected soils (Thomas and Middleton, 1993). Salinization occurs when the following conditions occur together (USDA, 1998):

- presence of soluble salts in the soil
- high water table
- high rate of evaporation
- low annual rainfall

Typical natural spots in semi-arid areas where salinization occurs are areas that receive additional water from below the surface which evaporates, leaving the salts behind, as at the base of hillslopes, the rims of depressions and the edges of drainageways and in flat, low-lying areas surrounding shallow water bodies (USDA, 1998). Human-induced salinization can be due to poor cultivation techniques; the indirect effects of irrigation schemes; vegetation change; sea water intrusion and disposal of saline wastes (Thomas and Middleton, 1993). A well-known example is the construction of the Aswan High Dam after which year-round irrigation was possible and the yearly flushing by the floods was halted (Conacher and Sala, 1998).
High levels of salt in the soil affect the ability of plant roots to take-up water, and the effect on plants is similar to that of drought. In the information sheet of the USDA (1998), some indicators of soil salinity are given as well as some suggestions of how to manage salinity problems. Saline soils cover an area of 1900 km^2 in the Iberian peninsula according to Conacher and Sala (1998). In the eastern Mediterranean and North Africa, there is progressive salinization of soils mainly in irrigated areas and low-lying areas which are subject to strong evaporation and rising groundwater tables (Conacher and Sala, 1998). For an overview of soil salinization in the Mediterranean see Postiglione (2002).

4.2.3. Land use and vegetation change

For the most part, vegetation change is the result of some degradation process, such as salinization or overgrazing or of human action, such as land use change due to the influence of subsidies or market fluctuations. As such, changes in vegetation can be both a cause and consequence of degradation. These changes in vegetation can subsequently lead to (further) desertification. However, changes in vegetation type or cover can also be an efficient remedy against degradation.
Land use changes are the result of environmental factors, but also complex political, social and economic processes play a role (Turner et al., 1995).

Agricultural change

Agricultural change and associated land management techniques can have a large effect on the status of an ecosystem and can be a driver of desertification. Almost all changes in agriculture use of a particular piece of land are driven by economic factors. The change from one particular crop to another brings with it other management and cultivation techniques (e.g. tillage). This change between crops can be induced e.g. by subsidies on certain crops. The change from agriculture to other forms of land use or *vice versa* can also induce degradation problems. An example of the former is the abandonment of former agricultural areas with the resultant collapse of conservation structures like terraces. Land management includes the conversion of rangeland or forested land to agricultural use. There is a wealth of literature on the causes and effects of land use change (e.g. Lambin et al. 2001; Taylor et al. 2002; Lambin and Geist 2006; Symeonakis et al. 2007).

Overgrazing and overexploitation

Various definitions of overgrazing are used and misused in scientific literature and the term is usually value-laden as it implies grazing at a higher level than desired relative to a specific management objective (Mysterud, 2006). In his paper concerning the role of overgrazing in the management of large herbivores, Mysterud (2006) gives several definitions from the points of view of various ecosystem management options. A general definition is 'an excess of grazing animals that leads to degradation of plant and soil resources'.

According to the Global Assessment of Human-induced Soil Degradation (GLASOD) survey conducted in 1990, overgrazing is the most important cause of degradation in dryland areas of Australia, Africa, Europe and Asia (UNEP, 1997). The reasons for concentrating too many livestock in certain areas, leading to loss of vegetation cover and trampling of the soil surface, may be political, cultural or socio-economic, while they may also result from environmental factors such as drought and the distribution of vector-borne diseases (UNEP, 1997). Overgrazing around settlements in North Africa is often related to the settling of the former nomadic herders.

Deforestation

Little of the indigenous vegetation remains in many parts of the Mediterranean Basin due to its long period of human settlement (Conacher and Sala, 1998). In common with many Mediterranean seasonally arid areas in Portugal, the indigenous mixed oak forest in Spain has been replaced almost entirely by *Cistus*-dominated *matorral* on hillslopes and by cultivated dryland farming on the plateaux (Conacher and Sala, 1998). Until the end of the 19th century, deforestation and exploitation of the residual forest constituted the main forms of degradation in southern France and Corsica (Conacher and Sala, 1998). These problems have been superseded by forest fire, floods, soil erosion and air and soil pollution. Deforestation seems to have caused desertification problems, but as deforestation is no longer a major issue in recent times (rather, reforestation is being done in many areas), this seems not to be a direct problem anymore.

4.2.4. Forest fires

Major wildfires commonly occur every 20-30 years in natural Mediterranean-type ecosystems, assisted by high air temperatures, low summer rainfall, fire-prone vegetation and dry fuel loads (Margaris and Koutsidou 2002). This vegetation is naturally adapted to fire which can be beneficial to physical, chemical and biological attributes of the landscape at low intensity, provided any grazing is controlled. However, widespread introduction of highly flammable fast-growing tree species (poplar, eucalyptus and pine) has not only reduced biodiversity, but also led during the 1990s to 600 000 ha of forest burning annually (FAO 2001), which is likely to rise in the future through global warming (McCarthy et al. 2001; Scholze et al. 2006). In Portugal, Spain and Italy, >3% of forests were burnt annually during this period (Scarascia-Mugnozza et al. 2000). Wildfires not only lead to landscape degradation through the temporary biomass loss, but also, and arguably more importantly, by affecting the physical and chemical properties of the soil and its structure, the nutrient status, and by causing a considerable increase in runoff and soil erosion during the post-fire ‘window of disturbance’, which can last for several years (Shakesby et al. 1993; Ferreira et al. 2000; Shakesby and Doerr 2006). Important off-site impacts include increased flooding and reduced water quality.

4.2.5. Flooding

Flooding as a desertification-related process may seem paradoxical. It is a secondary problem, as it is the consequence of other desertification-inducing processes, mainly water erosion and urbanization. Its effects are mostly outside the area (a so-called offsite effect) that is identified as a ‘desertification hotspot’. In these areas, as soils have become thin or even absent, water from torrential rainstorms is transported downstream quickly and in large quantities, leading to flooding of downstream areas. Urbanization leads to an increase of impervious surfaces, which also leads to the quick transport of water and flooding downslope. For example, streams draining the Catalan Coastal Ranges suffer from increased urban use of their watersheds and streambeds for housing, car parks and roads, as a result of which human and economic losses caused by flooding are often high (Conacher and Sala, 1998). However, floods are also associated with the Mediterranean area, because of the climatic characteristics of that area (i.e. torrential and very variable rainstorms). Floods constitute the second form of land degradation in the south of France and Corsica, examples of violent and sudden floods include that of 1940, 1986 and September 1992 (Conacher and Sala, 1998). See Sala (2003) for a study on (the increase of) flooding in a typical Mediterranean area.

4.2.6. Sedimentation and siltation

Like flooding, sedimentation and siltation (of reservoirs) are off-site effects of desertification through erosion. Sedimentation can harm existing crops but can eventually lead to an increase in productivity due to increase in soil thickness and quality. Siltation of reservoirs is mentioned in many papers (e.g. Symeonakis et al., 2007; Liquete et al., 2005, Mtimet et al., 2002) as an off-site effect of other desertification processes mainly erosion and land use change. The capacity of reservoirs has decreased significantly as a consequence (e.g. in Spain, Morocco, Algeria and Tunisia).

4.2.7. Loss of biodiversity

Land degradation affects biodiversity both directly and indirectly. In terrestrial land systems, physical and chemical processes of land degradation can destroy soil biota (earthworms, rhizobia, mycorrhizae) and alter and/or reduce vegetative cover. In aquatic and coastal systems, land degradation can affect the sediment flow and can thus indirectly affect the biodiversity of these systems, especially of coral reefs, mangroves and sea grasses. In some cases, this effect is exacerbated by the pollutants, including POPs, that might be absorbed to soil particles. There are also further feedbacks. For example, decreased productivity on farmlands due to land degradation can force farmers to clear additional areas of natural habitats to maintain production. Conversely, changes in biodiversity (e.g. introduction of exotic species, or of species that become invasive) can contribute to further land degradation. (Gitay, 2004).

Biological diversity is involved in most services provided by dryland ecosystems and is adversely affected by desertification. Most important, vegetation and its diversity of physical structure are instrumental in soil conservation and in the regulation of rainfall infiltration, surface runoff, and local climate. It is the disruption of the interlinked services jointly provided by dryland plant biodiversity that is a key trigger for desertification and its various manifestations, including the loss of habitats for biodiversity (See Fig. 4.1) (Millenium Ecosystem Assessment, 2005). The major components of biodiversity loss (in green) directly affect major dryland services (in bold). The inner loops connect desertification to biodiversity loss and climate change through soil erosion. The outer loop interrelates biodiversity loss and climate change.

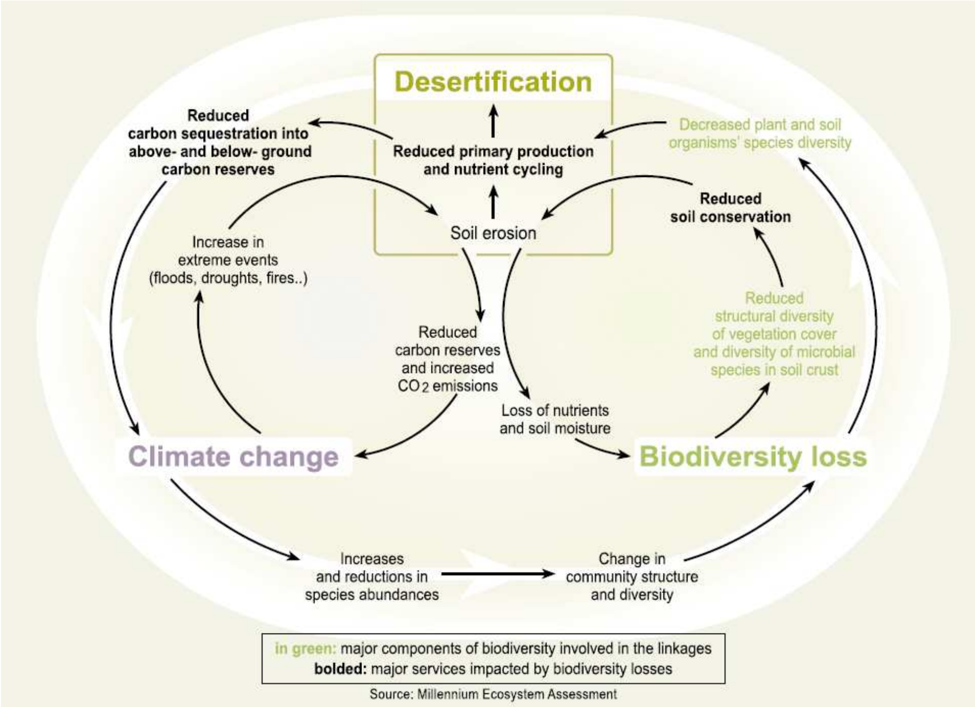


Fig 4.1 Linkages between Desertification, Global Climate Change, and Biodiversity Loss (from: Millenium Ecosystem Assessment, 2005).

4.3. Conclusions

Although difficult, we have attempted to separate processes and consequences from causes of desertification. Also, a distinction has been made between socio-economic and political processes on the one hand and biophysical processes on the other. While this is also difficult, an emerging conclusion is apparent: the *problems* of desertification (i.e. those issues that are connected to dryland degradation) are more of a bio-physical nature (see section 4.2), while their *causes* can be both bio-physical and socio-economic or political. It may also be that the socio-economic consequences of desertification are not as obvious or visible as the bio-physical problems. This is an important conclusion as it shows (once again) that when trying to solve or avoid desertification problems, not only bio-physical aspects should be assessed. As the bio-physical problems are more visible, this could easily lead to the assumption that solutions should also be sought in that area. However, this synthesis of causes and problems has shown, that desertification is a complex issue and as such, simple solutions will not work (see Chapter 7).

Chapter 5
Indicators: monitoring desertification

5. Indicators: monitoring desertification

As has been stated in the introduction (Chapter 1), the knowledge on current land degradation status or the magnitude of the potential hazard is mostly incomplete or fragmentary, and for some areas even entirely lacking (Pinet et al., 2006). It is essential to understand the extent of the desertification problem. Mapping the affected areas is not only needed for developing a more thorough scientific understanding of the dynamic processes and driving forces, it also forms an important requirement for the drafting and implementation of development plans and policy decisions about the sustainable use of Mediterranean land resources (Hill et al., 1995; Lacaze et al., 1996).
However, the environmental, social and economic complexities of land degradation make accurate assessment a difficult challenge, especially in dynamic semi-arid environments. Existing methods of degradation assessment rarely integrate different components of land degradation, focusing instead on single issues or academic disciplines. In particular, research to date has focussed on soil degradation, in particular on erosion rather than on solutions (van Lynden and Kuhlmann, 2002). In addition to this, it is often difficult to detect trends in degradation status over time, due to the use of unreplicable or incomparable methods. Assessments tend to be carried out by researchers for use by the local policy and academic communities. Local communities rarely participate, or receive results that can improve the sustainability of their land management. Acknowledging these limitations, researchers are increasingly recognising the value of multi-scale, multi-method studies that can assess degradation in the context of heterogeneous and dynamic local socio-economic, cultural and environmental conditions (LADA, 2001, 2004; Warren, 2002).
Different methods exist for evaluating desertification, including direct observation and measurement, mathematical models and parametric equations, estimates, remote sensing and indicators (Rubio and Bochet, 1998). While the mathematical modelling is dealt with in the next chapter, desertification indicators are assessed in this chapter, including techniques to monitor and map them.

5.1. History of monitoring

The first global attempt to quantify dryland degradation extent took place for the United Nations Conference on Desertification (UNCOD, 1977) in response to the Sahelian drought of the 1970s and (now discredited) research suggesting the southern limit of the Sahara was expanding by 5.5 km per year (Lamprey, 1975). The conference concluded that 3970 million hectares were desertified, an area four times the size of Europe (UNCOD, 1977). Despite the development of a provisional methodology for assessing and monitoring desertification by the FAO and UNEP in the 1980s, reliable data were still lacking at national and global scales and global assessments were still not based on systematic measurements. In 1984, with little new empirical evidence, UNEP revised their estimate to 3475 million hectares and in 1987 made the wild claim that because 27 million hectares were becoming desert each year, “in less than 200 years, at the current rate of desertification, there will not be a single hectare of fully productive land on earth” (UNEP, 1987). Figures of two-thirds to three-quarters of all drylands are still cited as being degraded (Diouf and Lambin, 2001; Eswaran et al., 2001). These assessments were challenged by a series of detailed remote sensing studies that showed the extent to which the location of desert margins can change in response to rainfall variability (Hellden, 1991; Tucker et al., 1991). This led some researchers to question the existence of dryland degradation (Warren and Agnew, 1988), suggesting it was an “institutional myth” (Thomas, 1993).

In response to this wide range of estimates, UNEP commissioned in 1987 a Global Assessment of Human-Induced Soil Degradation (GLASOD) from the International Soil Reference Centre (Oldeman et al., 1990). This indicated that 1016 to 1035 million hectares of drylands were degraded; less than a third of the area suggested by previous estimates. It was based on expert opinion, eliciting information about the type, extent, degree, rate and cause of soil degradation over the last 50 years from over 250 soil scientists and environmental experts in 21 regions of the world (Oldeman et al., 1990; UNEP, 1997). Despite being "the first scientifically systematic" assessment of land degradation, it has been criticised for various reasons, such as its subjectivity (e.g. Thomas et al., 1997). While claiming to assess trends over the last 50 years, few experts had personal experience of soil conditions in the 1940s, and there were few data available at this time for much of the world. The assessment does not take management goals or other contextual information into account. It does not involve local stakeholders who may have very different perspectives of land degradation. Related to this, it only provides information about one biophysical component of land degradation (the soil), ignoring other system components, notably ecological changes that are vital for semi-arid rangelands. Despite these problems and the fact that it is now fifteen years old, GLASOD is still cited in peer-reviewed literature (e.g. Conant and Paustian, 2002; Polyakov and Lal, 2004) and is still widely used by national and international policy-makers (ISRIC, 2003). It also forms the basis for the widely cited World Atlas of Desertification (UNEP, 1997).

5.2. Indicators

Land degradation indicators contain simplified, synthetic information on the state and tendency of complex processes such as desertification. They can be easily communicated to the public or policy-makers, they can be used as easy synthetic information in GIS systems to determine spatial extension and geographic distribution of degraded areas and to relate human actions (causes) to environmental conditions (effects) (Rubio and Bochet, 1998).

Land degradation indicators have the capacity to engage a wide range of stakeholders, from policy-makers to land managers, to provide interdisciplinary information about the nature of environmental change. Until now, scientists have not reached consensus about a standard set of indicators to use in monitoring desertification (Pinet et al., 2006). Such consensus is probably not possible or even desirable as conditions and processes leading to desertification show such (spatial) variability that it is impossible to monitor desertification in any place without a set of site-specific indicators.

Adaptive land management depends on effective monitoring to detect change as early as possible. However, it is increasingly claimed that existing indicators provide few benefits to users who as a consequence rarely apply them (Carruthers and Tinning, 2003; Innes and Booher, 1999). Partly, this is because indicators are usually developed by experts and applied without engaging local communities (Riley, 2001). Sustainable development literature and the United Nations Convention to Combat Desertification (UNCCD) stress the need for local communities to participate in all stages of project planning and implementation, including the selection, collection and monitoring of indicators (WCED, 1987; UNCCD, 1994; Corbiere-Nicollier et al., 2003). To do this, the methods used to collect, apply and interpret indicators must be in a form that can easily be used by non-specialists. To achieve widespread uptake, land degradation indicators must also be clearly linked to community needs, priorities and goals.

This is an enormous methodological challenge, but one that could bring many rewards. In the hands of local communities, degradation indicators have the potential to go beyond simply measuring progress. They can enhance the overall understanding of environmental and social problems and empower communities to respond appropriately to environmental change without having to rely on external experts. If the monitoring process can open a dialogue about land degradation with neighbours and policy-makers, indicators may be able to help relocalise and enrich land degradation policy decisions, and enhance the sustainability of local livelihoods.

Many indices have been proposed to describe the susceptibility of drylands to desertification (Pinet et al., 2006; and e.g. Tongway and Hindley, 2000). One of the most important issues is the identification of land degradation indicators which have a general applicability to the Mediterranean Basin as a whole and which can be observed with operational remote sensing systems (Hill et al., 1995, Lacaze et al., 1996). Indicators and approaches to develop and subsequently monitor them differ from expert-led, top-down to community-based, bottom-up (Reed et al., 2006). In their paper on the selection procedure of desertification indicators in Europe, Rubio and Bochet (1998) give a list of criteria to which indicators can be allocated.

As it is not the objective of this review to enumerate all possible desertification indicators, three projects are discussed here, that worked on indicator systems.

DESERTLINKS: DIS4ME

The major aim of the DESERTLINKS project (see Appendix II) was to contribute to the work of the UNCCD by developing a desertification indicator system for Mediterranean Europe. In their list of candidate indicators, a division is made between ecological, economic and social indicators. The indicator system (DIS4ME; Desertification Indicator System for Mediterranean Europe) contains about 150 desertification indicators of relevance to the Mediterranean. It has been designed to provide a tool to enable users from a wide range of backgrounds (including scientists, policymakers and farmers) to identify where desertification is a problem; to assess how critical the problem is and to better understand the processes of desertification. Each indicator is fully described and is available in a database allowing the user to select indicators according to various logical frameworks, temporal and spatial scales. An Environmental Sensitivity Index can be calculated by selecting values for 13 different indicators associated with vegetation, soil, climate and management. Details are available at the DESERTLINKS website (see Appendix II)

MedAction

MedAction (see Appendix II) aims at assessing the main issues underlying the causes and effects of land degradation; and at developing integrated policy options and mitigation strategies to combat desertification in the Northern Mediterranean region. They use a list of 65 indicators, subdivided into ecological (precipitation, soil, slope, vegetation, soil degradation), economic (income, prices, unemployment, equity, infrastructure, tourism, agricultural land use, consumption, trade), social (population, public perception) and institutional (subsidies, agricultural organisations, laws, European Union). The final key indicators that were selected by MedAction are given in Table 5.1. This table serves here as an example of potential indicators for use in DESIRE.

Table 5.1. List of key indicators, based on the hierarchy of the Factor and Sector tables. (From: Greeuw et al., 2001)

Sector	*Sub-sector*	*Key indicator*
Agriculture	Food crops	274 Land cover (ha, %)
	Animal products	276 Type and stocking density (no./ha)
	GI: Income from agric.	222 Crop and animal prod. prices ($)
Tourism	Eco-tourism	432 Area in parks (ha)
	Elderly Tourism	262 Destination of tourists
	GI: Water use	264 Water use by tourists (m^3/y)
Forest	Production	211 GDP from forestry ($/cap)
	Natural vegetation	144 Biodiversity (spec./ha)
	GI: Forest fires	145 Forest fires (no./year)
Factor	*Sub-factor*	*Indicator*
Water availability	Over-extraction	264/272/316 Total water use (m^3/yr)
	Water shortage	111 Rainfall (mm/yr)
	GI: Government intervention	431 Presence of national water laws (y/n)
Land degradation	Reduction of cover	see Sector Agriculture
	Soil degradation	151 Water erosion (ton/ha/y)
	Mis-management	271 Presence of land use practices (y/n)
	GI: Productivity loss	275 Crop yield (ton/ha/y)
Migration	Rural out-migration	311 Rural population density (no/km^2)
	In-migration	261 Number of tourists (no.)
	GI: Equity	Related to Economic stability
Economic stability	Employment	231 Unemployment rate (%)
	Equity	242 Poverty indices (-)
	GI: EU enlargement	443 EU budget shares ($/country)

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The prime goal of INDEX (Indicators and Thresholds for Desertification, Soil Quality and Remediation, see Appendix II) is to apply knowledge to develop modern, rapid, sensitive, universal, multivariate indicators with which the dynamic state of land degradation as well as its remediation can be assessed. The assessed indicators are subdivided into biological (bulk and molecular microbiological and enzymatic activities), humus (in terms of bulk, humo-enzymes and available humus) and physical (mineralogy and structure, soil hydraulics, particle size stability, pore size distribution and rheology) indicators.

5.3. Monitoring and mapping techniques

The assessment (extent) of desertification involves monitoring and mapping on various spatial and temporal scales. As direct monitoring/mapping of desertification is rather complicated, in most cases desertification indicators (see 5.2) are assessed. Depending on the (spatial) scale that needs to be monitored, different techniques are used. The Land Degradation in Drylands (LADA, see Appendix II) project aims to combine traditional and scientific knowledge to assess degradation severity and extent using a variety of techniques to measure environmental indicators, from local to national and international scales (Van Lynden and Kuhlmann, 2002). Van Lynden and Kuhlmann (2002) propose a combination of methods, including field monitoring, remote sensing, agricultural productivity change, expert opinion and land user perspectives. These techniques are briefly reviewed and discussed here. Modelling desertification (indicators) is covered in Chapter 6.

An overview of EU funded research into the monitoring and mapping of Mediterranean desertification can be found in Drake and Vafeidis (2004).

5.3.1. Field monitoring

Field surveys are still important and used in virtually all studies. The general disadvantages of field studies are the often high costs (due to instrumentation and personnel) and mostly small (local) scale. Advantages, however, include the very many parameters and processes that can be assessed, and although often biophysical characteristics of e.g. soil, landscape and climate are assessed, this approach is certainly not restricted to them. Human factors such as population dynamics, living standards etc. can be included (Van Lynden and Kuhlmann, 2002).

Indicators that are often assessed in field studies include rainfall characteristics, using rainfall gauges; vegetation status (e.g. vegetation cover, LAI, biomass etc); soil characteristics (e.g. soil moisture, aggregate stability, organic matter content); (ground)water salinization and landscape characteristics (mainly soil erosion features).
Methods that are required for the measurement of these parameters include (geo)statistics for soil sampling, a variety of measurement techniques for the assessment of erosion ranging from point, to plot and small catchment scales, laboratory analysis for soil properties etc. Many of these methods are also based, at least in their choice of where and when to measure, on expert opinion (see 5.3.2) and/or local knowledge.

5.3.2. Expert opinion

Qualitative assessment of degradation in the case of expert opinion is based on the perception by experts of the intensity of the degradation process (degree) and the impact on agricultural suitability, biotic function of decline in productivity (Van Lynden and Kuhlmann, 2002). An expert in this context is a scientist who has specific knowledge and experience in a certain field of work and specific geographical area (Van Lynden and Kuhlmann, 2002). Some degree of expert opinion, in any phase of a specific research or research project, is almost always applied. In some projects, expert opinion is explicitly named as a method of assessment. As has been said in the introduction, the GLASOD estimate of the extent of degraded drylands was based on expert opinion, eliciting information about the type, extent, degree, rate and cause of soil degradation over the last 50 years from over 250 soil scientists and environmental experts in 21 regions of the world (Oldeman et al., 1990; UNEP, 1997). By its nature, it is a qualitative and potentially subjective assessment (ISRIC, 2003). It is difficult to replicate; even if the same experts can be used, their perceptions of degradation may have changed unpredictably (van Lynden and Kuhlmann, 2002). An ongoing project that works with expert opinion is WOCAT (World Overview of Conservation Approaches and Technologies, see Appendix II; WOCAT, 2007). The WOCAT map method will also be used in DESIRE in combination with a method based on Remote Sensing (GLADA), see below.

5.3.3. Land user perspectives

It is now widely recognized that the views and interests of the land user as one of the most important stakeholders in the fate of the land is essential in assessing degradation and rehabilitation or prevention (Van Lynden and Kuhlmann, 2002; Geeson, pers. comm.., 2007). Land users often have the best local knowledge of land degradation and influencing factors. A disadvantage for the actual assessment phase might be the bias of the land user and his or her dependency on the outcome. However, the neglect of the land users' perception of (degradation) problems is perhaps one of the gravest omissions to date in land degradation and conservation research (Critchley, 2000). Above this, major advantages include more realistic measurements of actual field level processes, the assessment uses the integrated view of the ultimate client (i.e. the farmer or landowner) and results provide a far more practical view of the types of interventions that might be accepted by land users (Stocking and Murnaghan, 2001).

5.3.4. Remote sensing

The availability of remotely sensed data is increasing with the development of RS techniques and satellites. Pinet et al. (2006) give a summary of the theoretical background of Earth surface spectroscopy. Lantieri (2003) presents an exhaustive overview of remote sensing tools available today, including information on resolution, spectral bands, revisit capacity, swath, price levels, catalogues access and websites. The most common and cost effective remote sensing data used are high resolution (HR) and in particular Landsat TM (Lantieri, 2003). Radar images can also be used in cloudy areas - which in general has less relevance in dryland areas - but with a much lower performance than optical data (Lantieri, 2003). The remotely sensed data do not correspond directly with the information needed and must be interpreted to derive soil and vegetation parameters (Hill et al., 1995). For example, reflection data need to be converted to properties relevant for the soil erosion process, requiring detailed fieldwork to establish relations to be used for the conversion (Lacaze et al., 1996). On the other hand, the advantages of remote sensing are that large areas can be covered at relatively low cost, with a high temporal frequency. Applications of remote sensing for drylands include land cover, including vegetation types; land form and landscape; vegetation activity and growth; rainfall and related droughts; soil types and state (moisture, level of erosion); indicators based on climate and ecological modelling. It is possible to map directly land degradation features from remote sensing images, especially using HR or very high resolution (VHR) data. These features include (Lantieri, 2003):

- wind erosion patterns, in particular over large areas;
- salinization patterns in field crops of large irrigated schemes;
- overgrazing features, shown by low cover grasslands around animal paths for example;
- sedimentation of lakes or rivers and consequently upstream soil erosion;
- soil water erosion patterns, but only when of great size and over large areas (gullies);
- areas already burnt or areas subject to wildfire.

Under the GEF/UNEP/FAO project Land Degradation in Drylands (LADA), ISRIC uses Remotely Sensed NDVI data to assess changes in Net Primary Productivity (NPP) and Rain Use Efficiency (RUE) as proxy indicator for land degradation or improvement. This method (GLADA) will also be applied to DESIRE study sites.

In should be kept in mind, however, that field checking is important to characterize better the degradation types. Above this, not all land degradation features can be seen on satellite imagery, for example, sheet erosion, rills, fuelwood depletion, loss of soil fertility are not visible on RS data.

Projects that have focussed on monitoring desertification with the use of remote sensing techniques include ASMODE, CAMELEO, DESURVEY, DEMON I and II and DESERTSTOP (see Appendix II)

5.4. Concluding remarks

Being a complex process, monitoring of desertification is carried through the identification and assessment of indicators. Categories of indicators that play a role in desertification are ecological, economic, social and institutional. An interactive indicator system is DIS4ME that includes 148 indicators in its database. Monitoring and mapping of desertification (risk) is subsequently done by assessing the indicators through various techniques such as expert knowledge, land user perspectives, remote sensing and fieldwork. Remote sensing is robust and fairly accurate, but remains restricted to a physical state assessment of desertification. With expert opinion, the socio-economic aspect can also be assessed.

As desertification and land degradation are dynamic processes, monitoring their indicators should be a continuous activity and evaluation of the results should be done frequently. Caution should be taken in using maps of desertification risk, which have been used as if they were maps of actual desertification (Thomas, 1997).

Chapter 6
Modelling desertification

6. Modelling desertification

In most projects concerning desertification, modelling is included in at least one of the research stages. In this chapter, various aspects of modelling desertification will be discussed, including the function of models in desertification research, the process of modelling, a brief review of the type of models employed and the expected developments for the next decade. It is the objective of this chapter to describe models relevant to desertification research. Since many models exist that are in some way related to desertification, it is impossible to review or even list all of them here. Therefore, they are categorized in terms of theme, going from broad, globally applicable type of models (e.g. GCMs) through regional land surface models to detailed, regional or local hydrological or erosion models. A subdivision is made between biophysical and socio-economic modelling. In most categories, some well-known models are briefly described. Otherwise, the reader is referred to the given references provided for detailed information.

6.1. Definition of modelling

A model is a representation containing the essential structure of some object or event in the real world. Mulligan (2004) gives a review of research, funded by the EU, into modelling desertification. He states that to produce a model is to produce a simplification of reality. The purpose of a model is to formalise understanding gained through data collection or theoretical advance and to explore the properties of that understanding (Mulligan, 2004). However, this describes models that aim at understanding a (complex) system. Other models exist that are more practical and aim to be eventually applied by policy- or decision-makers. Three types of models are distinguished: conceptual, physical and mathematical models. The latter are often divided in empirical and physically-based. In scientific research, models are used as a tool for simplifying, formalising and testing theories as well as for implementing predictions of scenarios for future changes. They can be a means of understanding the system, testing of hypotheses and prediction and scenario development (Mulligan, 2004).

Process of Modelling

Mathematical modelling is the use of mathematical language to describe the behaviour of a system. The following stages are involved in the modelling process (Mulligan, 2004):

1. Model development
2. Parameterisation
3. Calibration
4. Verification and validation
5. Sensitivity analysis
6. Simulation and scenarios
7. Application

The process of verification and validation, while being one of the most important, is often neglected. Sensitivity analysis can assist in the understanding of the sensitivity of the real system and indicate which parameters are important and which are not. Eventually, a well understood, calibrated and validated model can be applied as a tool for (a) understanding the controls on some past change through comparison of modelled versus measured data, (b) simulation of future scenarios of change or (c) application to ‘what if’ type scenarios (Mulligan, 2004).

6.2. Model types

A wide range of model types exist that are appropriate to model the processes that contribute to desertification (Mulligan, 2004); from simple GIS-based desertification indices to complex, physically based multi-process simulation models and decision support systems. In between are models such as GIS-overlay models and empirical models based on field data. Empirical models are based on experience or experimentation and limited to conditions for which they have been developed (Aksoy and Kavvas, 2005). A model is called physically based when it has a physical representation of a (complex) system. For example, in erosion and sediment transport, when it is constructed by using the mass conservation equation of sediment (Aksoy and Kavvas, 2005). The smaller models can mostly be classified as empirical or physically based (Mulligan, 2004). The larger models are mostly a highly mixed and complex combination of empiricism and physical basis with a number of mathematical approaches adopted for different parts of the model.

The trend of an increase in the scales at which models are applied, as well as an increase in complexity of models, is reflecting the increase in computer power. Scales range from one-dimensional models, to two-dimensional hillslope models, to a current emphasis on three-dimensional distributed or GIS-based large scale models applied to catchment hydrology or atmospheric circulation (Mulligan, 2004). Although more complex models are more useful in understanding the system, they often fail in practical applications because of heavy data requirements (Mulligan, 2004). Simpler models are much more readily parameterised and are useful to understanding the reasons for past or present changes in an environmental system, but are less related to real-life situations (Van Lynden, pers. comm.) and not powerful enough to provide estimates or scenarios for future change (Mulligan, 2004).

6.3. Biophysical modelling

Categorization of models can be done according to several criteria, possibly including process description, scale, complexity or scientific theme or subject addressed. Here, models are classified based on themes that are relevant to desertification:

- Climate (i.e. modelling climatic variability and climate change (GCMs))
- Land surface – atmosphere exchange: Soil Vegetation Atmosphere Transfer models (SVATs)
- Land surface models
- Vegetation models
- Erosion and hydrological models

6.3.1. Climate

Modelling climate variability and ultimately climate change is done using climate models. These use quantitative methods to simulate the interactions of the atmosphere, oceans, land surface and ice. Climate models can range between simple zero-dimensional models of the radiative equilibrium of the earth to complex coupled atmosphere-ocean global climate models. In between are energy-balance models, in which horizontal energy transport in the atmosphere is considered, and EMICs (Earth system Models of Intermediate Complexity) bridging the gap between conceptual models and GCMs. One of the most common uses of climate models is to explore the impact of perturbations caused by human activity (Pitman, 2003).

EMICs: Earth system Models of Intermediate Complexity

To bridge the gap between conceptual, inductive, simple on the one hand and comprehensive, quasi-deductive models on the other, Earth system Models of Intermediate Complexity (EMICs) have been proposed (Claussen et al., 2002, see Fig. 6.1). These describe the natural earth system excluding the interaction of nature and humans. EMICs include most processes described in comprehensive models, but in a more reduced (parameterized) form. They explicitly simulate the interactions among several components of the natural earth system, mostly including biogeochemical cycles (Claussen et al., 2002). On the other hand, they are simple enough to allow for long-term climate simulations over several thousands of years. A list of currently existing EMICs can be found through the website of the Potsdam Institute for climate impact research (Claussen, 2005). The latest update is May 2005 and updating is done every two years, when new EMICs are included in the table [4]. For every model, the principal investigators are given, its scope, the model components, its limitations and performance, the applications and references.

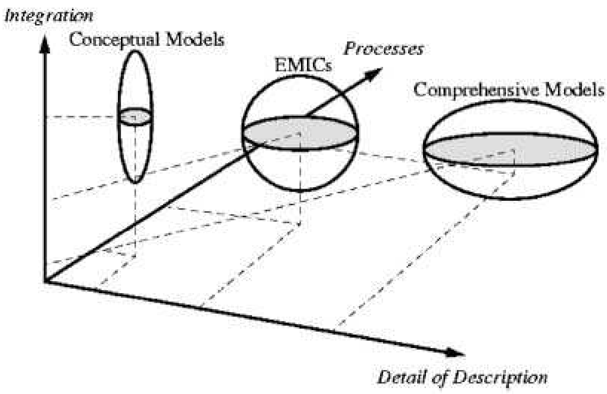


Fig. 6.1: Graphical definition of EMICs (from: Claussen et al., 2002)

GCMs: Global Climate Models or General Circulation Models

Global Climate Models, or General Circulation Models aim to describe climate behaviour by integrating a variety of fluid-dynamical, chemical or even biological equations that are either derived directly from physical laws or constructed by more empirical means. Both atmospheric GCMs (AGCMs) and oceanic GCMs (OCGMs) exist, which can be coupled to form an atmosphere-ocean coupled general circulation model (CGCM), integrating the knowledge on atmospheric and oceanic circulation (Grassl, 2000). A recent trend is to extend GCMs to become earth system models that include submodels e.g. for atmospheric chemistry or carbon cycling.

Extensive information on climate change, including model evaluation, can be found in the IPCC TAR report (IPCC, 2001).

Two well-known CGCMs are HadCM3 (Hadley centre Coupled Model, version 3; described by Gordon et al. (2000) and Pope et al. (2000)) and CGCM3 of the Canadian Centre for Climate Modelling and Analysis (CCCma) and Flato et al., 2000). A list of 21 models, about all CGCMs existing at the time, that participated in the first phase of the CMIP project (Coupled Model Intercomparison Project) is given in Meehl et al. (2000).

In his review, Mulligan (2004), states that it is increasingly certain that greenhouse induced global climate change will have significant effects on regional climates of the Mediterranean. A general increase in temperature is fairly certain, but the impact on regional rainfall and evapo-transpiration in the Mediterranean is much less certain and local scale impacts are very unclear (Mulligan, 2004). Further advances and results of projects using GCMs for predicting regional climate change in the Mediterranean (notably the MEDALUS project) can be found in Mulligan (2004).

6.3.2. Land surface – atmosphere exchange

The nature of a land surface affects the land surface–atmosphere energy, water and momentum exchange. This characterizes the regional planetary boundary layer which controls the regional climate (Mulligan, 2004). To study these interactions between soil, vegetation and atmosphere, so-called Soil-Vegetation-Atmosphere Transfer (SVAT) models are developed (Dolman et al., 2001). Their purpose is to provide coupling between the near-surface atmosphere and the hydro-ecological processes that take place in the zone that extends typically from a few metres below the ground, through the vegetation into the lower

[4] An update for 2007 was not available yet at the time of writing (August 2007).

atmospheric boundary layer (Shuttleworth, 2005). SVATS are the main mechanism by which complex land surface-atmosphere processes are integrated in GCMs (Mulligan, 2004). The upper boundary conditions are incoming solar and long-wave radiation, precipitation, atmospheric variables such as temperature, humidity and wind speed and if relevant, concentration of atmospheric constituents. In most SVAT models, the lower boundary conditions are weakly specified: often gravity drainage of soil water to a remote, unspecified groundwater table is assumed (Shuttleworth, 2005).

In the EFEDA II project a significant modelling effort was made, concentrated on the development of regional SVATS (Mulligan, 2004). As with GCMs, many SVATS exist. In Moran et al. (2004) and references therein, several SVATS are named. Comparison over wheat fields of several SVATS of varying complexity is done by Olioso et al. (2002).

6.3.3. Land surface models (LSMs)

The land surface is a key component in climate models, controlling the partitioning of energy between sensible and latent heat and of water between evaporation, infiltration and run-off (Pitman, 2003). Changes in land use are directly linked to many environmental problems at both global and regional scale, and are intrinsically related to the evolution of the regional and global climate (Salmun and Molod, 2006). Land surface schemes or models account for the parameterization of the surface and subsurface mass and energy transfers (Salmun and Molod, 2006). The character of the land surface is spatially variable (e.g. variability in vegetation cover, terrain type, soil texture and wetness etc), complicating calculations of land-atmosphere exchange. Mostly, the scale of heterogeneity is (much) smaller than the grid scale used in GCMs (about 200km). Techniques to account for this include ‘dominant’, çomposite’, ‘mosaic’ and recently ‘extended mosaic’ (briefly explained in Salmun and Molod, 2006). Using these land surface models, many studies have been conducted to simulate the impact of land cover changes on regional or even global climate. A summary concerning (tropical) deforestation and desertification is given in Salmun and Molod (2006).

Within a climate model (e.g. a GCM), the element that simulates the initial effect of land cover changes is the land surface model. The evidence is very strong that regional-scale land surface perturbations cause continental-scale changes in climate (Pitman, 2003). In his comprehensive review, Pitman (2003) argues why the land surface should be important in climate models, including a description and examination of the historical development of LSMs.

6.3.4. Vegetation models

Vegetation cover provides a dynamic feedback between the atmosphere and the soil and land surface. Impacts of vegetation change may have strong effects on hydrology, geomorphology (e.g. protection against erosion) and climate and at the same time affect humans and livestock as it provides a means of food (Mulligan, 2004). Vegetation response to environmental change therefore, is an important issue and the modelling of vegetation changes is discussed here in two parts: vegetation models as part of a GCM and as smaller scale independent models.

Dynamic Global Vegetation Models (DGVMs)

Following the relationship between global patterns of vegetation cover and climate, several models of global vegetation patterns have been developed, e.g. BIOME (Prentice et al., 1992), BIOME-3 (Haxeltine and Prentice, 1996), MAPSS (Neilson, 1995) and DOLY (Woodward et al., 1995). Changes in climate affect the distribution of global vegetation communities, while vice versa changes in vegetation structure may significantly influence the climate (see examples in Foley et al., 2000 and references therein) at several timescales. While most climate models describe the rapid biophysical processes, longer-term ecological phenomena are not yet considered (Foley et al., 2000). In most land surface models, vegetation and soil

properties are prescribed as boundary conditions which are not allowed to change with the climate, neglecting long-term changes in vegetation cover and resultant feedbacks (Foley et al., 2000). With the advance of Dynamic Global Vegetation Models (DGVMs), the coupling of vegetation models in which long-term changes in vegetation dynamics with GCMs has become possible, using various coupling techniques (see examples in Foley et al., 2000).
A well-known DGVM is the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ) which combines process-based, large-scale representations of terrestrial vegetation dynamics and land-atmosphere carbon and water exchanges in a modular framework (Sitch et al., 2003).

Smaller scale independent vegetation models
The aforementioned bio-geographic models are used to predict broad-scale patterns in vegetation for regions, continents and the globe. Another type of models used to predict vegetation dynamics, acting on a smaller scale (<1 to 100 m^2), are the species-based successional models or gap models (e.g. Pausas, 1999; Sitch, 2003 and references therein; Peters, 2002). These simulate the recruitment, growth and mortality of individual plants and complex interactions such as landscape-scale processes and feedbacks between vegetation and soil processes can be represented by these models (Peters and Herrick, 2001). However, they are limited computationally in the spatial extent that can be simulated, due to the small plot size and detailed processes included. Attempts to extend their spatial scale include linking gap models with landscape-scale models (Peters and Herrick, 2001).

The Mediterranean
Two models focusing on the Mediterranean area are the vegetation components of the MEDALUS model and the ModMED model. They will be briefly discussed here.
The MEDALUS model is described in Kirkby et al., (1996) and the vegetation part is reviewed in Mulligan (2004). The vegetation component of the MEDALUS model plays an important role in the hydrological budget and in predicting erosion (Mulligan, 2004). Given the diversity of the Mediterranean vegetation, a model with a number of functional types with clear distinction between herbaceous primary grassy vegetation and woody types, thus a grass and a shrub model, are developed. The model has a large number of parameters, requiring an intensive field effort (Mulligan, 2004).
ModMED, acronym for Modelling Mediterranean Ecosystem Dynamics, aims at predicting the development of vegetation patterns in the landscape in response to changes in land use. The model simulates the processes of ecosystem dynamics integrating knowledge on the plant, community and landscape scale. While the primary objective of the model is to make predictions of vegetation change at the landscape scale, the fundamental principle behind it is that successful predictions result from modelling the system at a lower level; at the community and individual levels (Mulligan, 2004).

6.3.5. Erosion and hydrological models

There are many erosion and hydrological models, which makes it impossible to name them all here. A general overview of categorisation of erosion models is discussed and some well-known models are mentioned. Furthermore, models are reviewed in extensive reviews, such as Aksoy and Kavvas (2005) and Merritt et al., 2003, to which is referred for detailed comparison between erosion models.
Morgan and Quinton (2001) describe the history of erosion modelling, whereby the need to evaluate soil conservation practices is seen as the impetus for developing erosion models. They divide the models into empirical and process-based models. Aksoy and Kavvas (2005), in their review of hillslope and watershed scale models, discuss conceptual models apart from empirical and process-based ones, which is also done by Merritt et al. (2003) in their extensive review of erosion and sediment transport models. An overview of the 17 models reviewed by them is given in their paper, including type of model, scale, input requirements and reference.

Empirical models

Empirical models are based on determining statistically significant relationships between an intended model output and model inputs. The Universal Soil Loss Equation (USLE) is the most widely-used empirical model, with its greatest advantage being its simplicity. The disadvantage of all empirical models is that they are only valid for the database and conditions for which they were derived (Morgan and Quinton, 2001; Aksoy and Kavvas, 2005). Other examples of empirical models include the Soil Loss Estimator for Southern Africa (SLEMSA), the Morgan-Morgan-Finney (MMF) model, adapted by De Jong (1994) to the Soil Erosion Model for Mediterranean Areas (SEMMED). See also the list of models and reviews of individual models in Aksoy and Kavvas (2005).

Process-based models

Physics-based models use mathematical relations to describe the processes of erosion and simulate the movement of water and sediment over the land surface (Morgan and Quinton, 2001). As many of the equations still have an empirical base, these models are considered to be process-based rather than physics-based. They typically contain separate runoff and erosion components and employ some form of kinematic wave procedure for routing water and sediment (Morgan and Quinton, 2001).

A very large number of process-based models have been developed. Division between them can be made based on various criteria. A list of properties of 12 well-known physically-based erosion models is given in Aksoy and Kavvas (2005). Morgan and Quinton (2001) divide them in two broad groups: continuous simulation models and event models. The first require large amounts of data and are used to assess the long-term effects of land management of climatic change on run-off and erosion. Examples include CREAMS (Knisel, 1980); WEPP (Nearing et al., 1989), SEM/SHE (Storm et al., 1987) and PESERA (Kirkby et al, 2004). Event models, simulating the response of catchments to single storms, require less data but they do require assumptions about the starting conditions for each event. Examples include ANSWERS (Beasley et al., 1980); KINEROS2 (Woolhiser et al., 1990); GUEST (Misra and Rose, 1990); EROSION 2D/3D (Schmidt, 1991); LISEM (De Roo et al., 1996a,b) and EUROSEM (Morgan et al., 1998). Differences in the approach to simulate the erosion processes are described in their review (Morgan and Quinton, 2001).

6.4. Socio-economic and participatory modelling

Increasingly sophisticated models are being used to represent the kinds of highly complex environmental, economic and social systems found in drylands susceptible to desertification. Modelling has primarily been used by natural scientists as a means of capturing and predicting aspects of these systems, usually within disciplinary boundaries (e.g. hydrology, soil or atmospheric models). Economists also have a fairly long tradition of modelling components of socio-ecological systems, especially human-environment interactions (Bergh and Straaten, 1997, Clark, 1976).

For example, regional economic models (based on input-output analysis) can provide quantitative information about production and consumption in a dryland economy, for example quantifying economic outputs from agriculture and effects on water consumption, pollution or soil degradation. Such models can be used to analyse how different future scenarios (e.g. changes in lifestyles, growth or decline of certain economic sectors, social or economic policies, or changes in availability of natural resources) might affect land management within the production-consumption cycle (Duchin and Hubacek 2003; Duchin and Lange 1994).

More recently, sophisticated social models such as agent-based models (ABMs) have begun being used in environmental disciplines to describe and predict the way people ('social agents' or 'stakeholders') are likely to behave in response to different stimuli given various decision-rules (Gilbert and Troitzsch, 1999, Janssen, 2002). However, these models tend to treat the environment as a static system (Matthews, 2006). In order to better approximate feedbacks and more accurately represent the complexity of real-life systems, dynamic models can be integrated from different disciplines. In this way it is possible to predict how people may respond to environmental change, and how their responses in turn are likely to influence their environment. Accurately representing human behaviour in ABMs requires inputs from the people who live and interact with the systems (e.g. landscapes) one is trying to model. This involves deriving “rules of behaviour” from the actual experiences, opinions and perceptions of real-life social agents.

Researchers are increasingly taking inputs from stakeholders beyond the construction of social models, collaborating with them to build and integrate models in what is known as “mediated modelling” (van den Belt, 2004). This offers a number of advantages, as social agents are often intimately acquainted with a level of complexity and detail that is rarely represented in computational models. Participatory modelling has a relatively long history. Since 1969 a decision making process has been evolving to address the twin challenges of learning and management in complex systems. This process, known as “adaptive management”, has been refined in a series of on-the-ground applications in problems of forestry, fisheries, national parks, and river systems (Holling, 1978, Walters, 1986, Gunderson and Holling, 1995, Gunderson and Holling, 2002, Walker et al., 2002, Sendzimir et al., 2007, Magnuszewski et al., 2005).

6.5. Gaps and progression in modelling

From the above it is clear that it is impossible to comprehensively model desertification. However, much work has been done to model the various components and processes of desertification, both socio-economic and biophysical aspects. Also, various spatial scales are assessed in various projects, from plot and hillslope scale to European scale (e.g. PESERA).

According to Mulligan (2004), the main progress expected in the next decade concerns the process of modelling itself. In his review, expected progress regarding several topics of desertification modelling is described, which is summarized here:

- improvement in techniques and technologies for downscaling GCM scenarios to the catchment scale;
- deeper understanding of the land surface in determining regional climates and the impacts of land use change on surface fluxes;
- SVATs being able to deal with land surface – atmosphere fluxes over the whole seasonal cycle;
- Hydrological modelling improvements will be in the field of smaller grid sizes, better DEMs, a greater emphasis on physical reality than empiricism and importantly parameterisation and validation;
- Overland flow and erosion research is highly developed and the focus will shift towards nutrient loss or landslides
- Greater emphasis on modelling the ecology of semi-arid vegetation, including interactions between functional types and at the species level, nutrients, species survival and loss of biodiversity due to desertification, the role of genetic variability, etc.;
- Continued integration between physical, biological and socio-economic models, providing decision support against scenarios for environmental change.

Chapter 7
Solutions

7. Solutions

Next to the many projects and research on the processes, causes and extent of desertification, many solutions to desertification related problems (e.g. land degradation) have been proposed. As desertification problems are complex (e.g. Thomas, 1997), so are solutions (WOCAT, 2007). Reynolds et al. (2007) defined five lessons learned about sustainable development in the drylands, all of which show the complexity of the problem: (1) Integrated approaches are needed; (2) Short term measures cannot solve slowly evolving conditions; (3) Dryland systems have nonlinear processes; (4) Cross-scale interactions must be anticipated; and (5) Greater value must be placed on local environmental knowledge.

Solutions to desertification or land degradation in drylands have been applied since ancient times. Examples include terraces, irrigation schemes, water harvesting etc. The first in particular, though effective in reducing erosion, need constant maintenance. Solutions and problems can be interrelated, e.g. grazing by animals can help reduce the risk for forest fire (Conacher and Sala, 1998) but at the same time may lead to overgrazing problems if not controlled properly. In this chapter, some solutions and basic principles are given, but these should be evaluated locally in their physical and socio-economic context. Even where solutions and remedial actions have been successful, they may not be simply transferable from one location to another, due to differences in the physical environment but also because cultural differences may make the components of the necessary actions unacceptable or difficult to apply (Thomas, 1997). For an extensive analysis of soil and water conservation worldwide (i.e. not restricted to desertification or the Mediterranean), see WOCAT (2007).

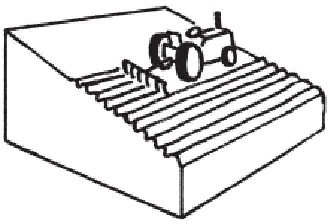
There are no simple ‘silver bullet’ solutions to the complex problems of land degradation. It is therefore important to understand the ecological, social and economic causes of, and processes behind, degradation, to analyse what works and why, and how to modify and adapt particular technologies and approaches to locally specific circumstances and opportunities. Solutions need to be flexible and responsive to changing complex ecological and socio-economic environments. An urgent and specific area for further investigations and research is quantification and valuation of the ecological, social and economic impacts of SWC, both on-site and offsite, including the development of methods for the valuation of ecosystem services. SWC research should seek to incorporate land users, scientists from different disciplines and decision-makers. A continuous feedback mechanism is needed to ensure active participation of these stakeholders.

Although obviously they should be implemented in a combined way, a division is made here between several types of biophysical solutions and political and socio-economic types of solutions. However, it is recognised that any biophysical solution needs a social background of acceptance before it will be effectively adopted and implemented.

7.1. Biophysical solutions

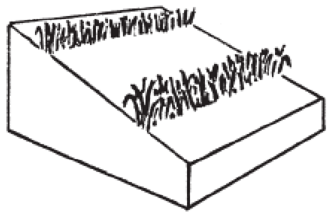
Some solutions to desertification are given here. However, as indicated by the complexity of the desertification problem, a single solution will not solve it. Moreover, there should be the recognition that prevention is the most cost-effective solution to degradation.

Biophysical solutions can be categorised into a few major groupings (WOCAT, 2007), see Figure 7.1.



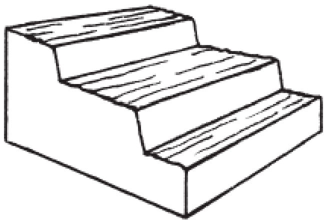
Agronomic measures such as conservation agriculture, manuring/ composting, mixed cropping, contour cultivation, mulching, etc

- are usually associated with annual crops
- are repeated routinely each season or in a rotational sequence
- are of short duration and not permanent
- are often not zoned
- do not lead to changes in slope profile
- are normally independent of slope



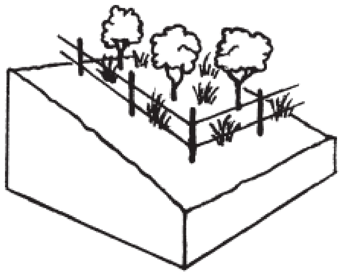
Vegetative measures such as grass strips, hedge barriers, windbreaks, or agroforestry, etc

- involve the use of perennial grasses, shrubs or trees
- are of long duration
- often lead to a change in slope profile
- are often aligned along the contour or against the wind
- are often spaced according to slope



Structural measures such as terraces, banks, bunds, constructions, palisades, etc

- often lead to a change in slope profile
- are of long duration or permanent
- are carried out primarily to control runoff, wind velocity and erosion
- often require substantial inputs of labour or money when first installed
- are often aligned along the contour or against the wind
- are often spaced according to slope
- involve major earth movements and/or construction with wood, stone, concrete, etc

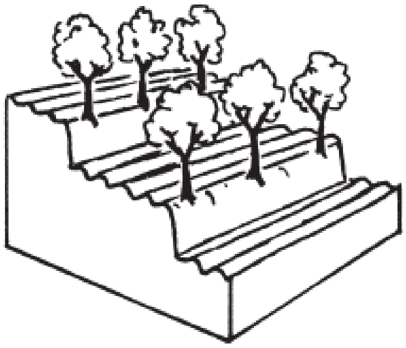


Management measures such as land use change, area closure, rotational grazing, etc

- involve a fundamental change in land use
- involve no agronomic and structural measures
- often result in improved vegetative cover
- often reduce the intensity of use

Figure 7.1: categories of Soil and Water Conservation (SWC) measures

A solution (or *practice*) may fall within one of the above categories, but very commonly also consists of a combination of these. These combined measures – overlapping, or spaced over a catchment/ landscape, or over time - tend to be the most versatile and the most effective in difficult situations: they are worthy of more emphasis (WOCAT, 2007).



Combinations in conditions where different measures are complementary and thus enhance each other's effectiveness.
Any combination of the above measures is possible, eg:

- **structural**: terrace
- **vegetative**: grass and trees
- **agronomic**: mulching
- **management**: fencing off

Below follow a number of bio-physical solutions that address one or several specific degradation problems.

Water conservation/harvesting

In dry areas the availability of water is of prime importance. One of the basic principles to achieve this is conservation and/or harvesting of surface and groundwater and soil moisture. Irrigation techniques should be optimised, e.g. drip irrigation is more water efficient than sprinkler or flow irrigation (Portnov and Safriel, 2004). Techniques like mulching and minimum tillage reduce evaporation losses. Terraces and cross-slope barriers like hedges, trash or stone lines reduce the speed of the water flow and thereby enhance infiltration. Water can also be actively harvested from rainfall or streams by diverting it to above or underground storage reservoirs or more simply in the field by creating mini catchment basins such as the "half-moon" technique practiced in N. Africa.

Technical solutions to the water problem in Spain include the building of many reservoirs, the transfer of water and desalinization of seawater (Conacher and Sala, 1998). Especially the second gives rise to much debate and should be used with caution as it changes the waterbalance in both receiving and supplying watersheds and can have unforeseen results. The avoidance of leakages in water distribution networks and an increase of the awareness that water is scarce to the population could also help in increasing water use efficiency (Conacher and Sala, 1998). Stabilizing channel walls with sometimes massive techniques in France is not considered a durable solution as undermining by the current will eventually lead to the collapse of the structure.

In the eastern Mediterranean, waste-water is being treated and re-used for irrigation or to replenish the coastal aquifer (Conacher and Sala, 1998).

Erosion reduction

The majority of measures to control land degradation is aimed at reducing or preventing erosion. Erosion control can be achieved essentially in two ways: reducing the sensitivity of the soil to eroding agents (erodibility; e.g. increase the soil organic matter content, reduce or break up the slope, cross-slope barriers) and reducing the impact of rainfall erosivity e.g. by increasing vegetation cover (Stroosnijder, 2000). Structural measures against various forms of erosion are widespread (terraces, gully plugs, check dams, etc.) but are not always the most (cost-)effective. While generally successfully reducing run-off and sediment transport, the erosion problem itself is not always solved: e.g. while upstream erosion is reduced, it is increased downstream due to the higher erosive power of the clear water (Hook and Mant, 2000; Conacher and Sala, 1998). Moreover, terraces may stop erosion but not necessarily increase yields and income. A live or dead vegetative cover in vineyards , e.g. with grasses or mulch, is a very efficient and (more) cost-effective means of preventing soil erosion. Reforestation is another popular but increasingly challenged solution. Plantations of Aleppo pines and eucalyptus trees were established in Italy, notably in the 1960s and 70s to reduce erosion. They have proved to be of limited benefit, as following an initial phase of reduced soil loss, a resurgence of erosion normally occurs and severe piping develops (Sorriso-Valve et al., 1992, 1995).

In northern Africa, a widely used conservation technique is stone bunds built with large stones and rocks that are removed from the field. The bund reduces the speed of run-off water and allow the natural creation of small terraces. They also hinder the entrance of livestock on the fields thereby reducing the damage of (over)grazing and browsing.(Conacher and Sala, 1998).

Conservation agriculture is increasingly being applied, e.g. in southern Spain (Conacher and Sala, 1998). It is not a single measure but a broad concept which includes minimum tillage, crop rotation, optimum soil cover, direct seeding and the correct use of herbicides, the need for which is increased by the reduction of ploughing. In Greece, soil erosion is being controlled by a system composed of conservation tillage, contour farming, terracing, grassed waterways and maintaining a rich vegetation cover (Conacher and Sala, 1998).

Grazing management
The issue of overgrazing is often related to the political desire of settlement of nomadic people. However, herds in dryland areas should be allowed to follow the rains. If this is neglected, year-round grazing at one specific location may lead to overgrazing. Enclosing pastures, i.e. part of the grazing land is closed to grazing livestock to allow the pasture to recover naturally, may work for that particular piece of land, but it increases pressure on other parts, possibly exacerbating the problem (Fan and Zhou, 2001). Planting of improved grass and (other) fodder species either or not in combination with stall feeding may also provide a solution.

Salinization
Salinization is another common problem in dryland areas, especially under irrigation. This can occur when land is irrigated and no appropriate drainage system is in place. With the capillary rise of the water salts are transported to the surface and remain there after the water evaporates. Proper drainage or other measures to lower the water table (e.g. planting poplars in Kyrgyzstan, WOCAT, 2007) is a possible solution while the irrigation water should also be of good quality.

Wildfire control
Land degradation by wildfires can be tackled in two main ways: fire hazard reduction and post-fire remediation. In the former, fuel load reduction methods and forest and land management practice changes are aimed at limiting the spread and degree of destruction by wildfire. The fuel load can be reduced by means of understorey clearance, herbicides, grazing and ploughing at the individual tree, tree stand and forest scales. Improved choice of tree species to match the climatic and topographic characteristics to reduce the impact of wildfire has also been proposed. These measures have been discussed with respect to Portugal (see chapters in Silva 2002). An alternative approach is prescribed fire, which involves burning the understorey and litter under controlled conditions to reduce the destructive effect of any subsequent wildfire. Following realisation of the disastrous effects of fuel load build-up resulting from attempting to suppress all fires, it has been become an accepted tool in North America during the late 20th century (e.g. Neary et al. 1999) and Australia (e.g. Morrison et al. 1996), but it has been only relatively recently been considered in Portugal (Fernandes and Botelho 2003).

As regards post-fire remediation, measures can be divided into three categories: emergency stabilization, rehabilitation and restoration. Emergency measures include mulching to prevent soil erosion, the introduction of barriers (e.g. log barriers) at strategic points in the burnt landscape to intercept particularly erosive overland flow and reduce soil erosion (e.g. Marqués and Mora 1998; Fox et al. 2006) and the planting of grass 'filter' strips (Robichaud 2005). Rehabilitation encompasses activities undertaken over several years to repair roads, bridges etc. and plant trees and reduce fuel loads. Restoration refers to longer-term measures aimed at improving the resilience and maturity of the ecosystem (e.g. Vallejo and Alloza 1998; Silva 2002b; Espelta et al. 2003). For the DESIRE project, it is intended to assess the effectiveness of some of these measures about which little is known in the Mediterranean context, especially prescribed fire and emergency post-fire mitigation measures.

7.2. Political and socio-economic solutions

While bio-physical solutions are important at the field level, these need to be embedded in an enabling environment. Without such an environment a certain solution may work perfectly in one area, but not at all in another, in spite of similar natural conditions. WOCAT (2007) defines this as the "Approach": "the ways and means of support that help introduce, implement, adapt and apply SWC technologies on the ground". This includes a variety of factors such as training and extension, markets, socio-cultural issues, participation, credit facilities, legislative and political issues, etc. Perhaps even more than with bio-physical measures, these "approaches" consist most often of a combination of different measures and are often framed in a project or programme strategy. It is therefore difficult to highlight specific single solutions in this respect but a few important elements can be highlighted:

- *Incentives* can be used to solicit or enhance the support of local stakeholders. They may vary from straight payments (subsidy) for services delivered to in-kind contributions of seeds or other materials. Food-for work is another incentive strategy that was widely used by the World Food Programme in Ethiopia in the 1970's. There is a risk with this type of incentives of "buying" peoples participation rather than make them feel responsible for the end results. Free training and extension can also be considered a form of incentive and may contribute more to this feeling of ownership – see also next point.
- *Participation* of local stakeholders can play an important role in making a solution a success or a failure. Various levels of participation can be distinguished from passive (e.g. only being informed) through active – with or without payment – to self-mobilisation. It is generally believed that with higher levels of active participation, the chance of successful solutions also increases, though contradictory examples can be found on either side.
- *Training and extension* Broadly speaking, there are three forms of extension and training (WOCAT 2007):
    - The 'multiple strategy'. This is what is adopted by the majority of the project/ programme-based approaches. It includes several or all of the following: awareness-raising, training workshops and seminars around specific themes, exposure visits, hands-on training, and the use of demonstration plots.
    - The second main form is based on informal farmer-to farmer extension and exchange of ideas. Here projects assist through facilitating exchange between farmers: for example by enabling farmers to visit each other for mutual learning.
    - The third is centred on the use of trained 'local promoters'. These are basically local farmers who are trained to become facilitators/ extension workers under a project.

  In many developing countries formal extension services are in place, that may not exist as such in Europe, where commercial agricultural consultants may provide (paid) advice to the farmers, but increasingly the use of Internet and other media helps to spread the implementation of appropriate solutions.
- *Land tenure and land use rights* can have a great impact on the uptake of specific measures. In many countries land users are reluctant to make long-term improvements to their land because they have no security of the land, or to be seen as putting an (illegal) claim on the land. There is a broad consensus that more land security enhances the chance of success of measures to control degradation.
- *Research* can be a very effective instrument for inventing new solutions or improving old ones, or to determine the suitability of specific measures for specific locations. It may support or defy certain assumptions and preconceptions that form the basis of many promoted solutions. Research also increases the understanding of the underlying processes and driving factors and it exposes and fills knowledge gaps (Liniger and Douglas, 2004)

References

Appendix I: The DESIRE project
Appendix II: Previous and ongoing projects

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Appendix I: The DESIRE project

1. The DESIRE project

The full title of the DESIRE project is: “Desertification Mitigation and Remediation of Land, a global approach for local solution”. Based on the detailed understanding of the functioning of fragile semi-arid and arid ecosystems (see Fig. I.1), development of integrated conservation approaches can contribute significantly to prevent and reduce the widespread and on-going land degradation and desertification processes. The final goal of the DESIRE integrated project is the establishment of promising alternative land use and management conservation strategies.

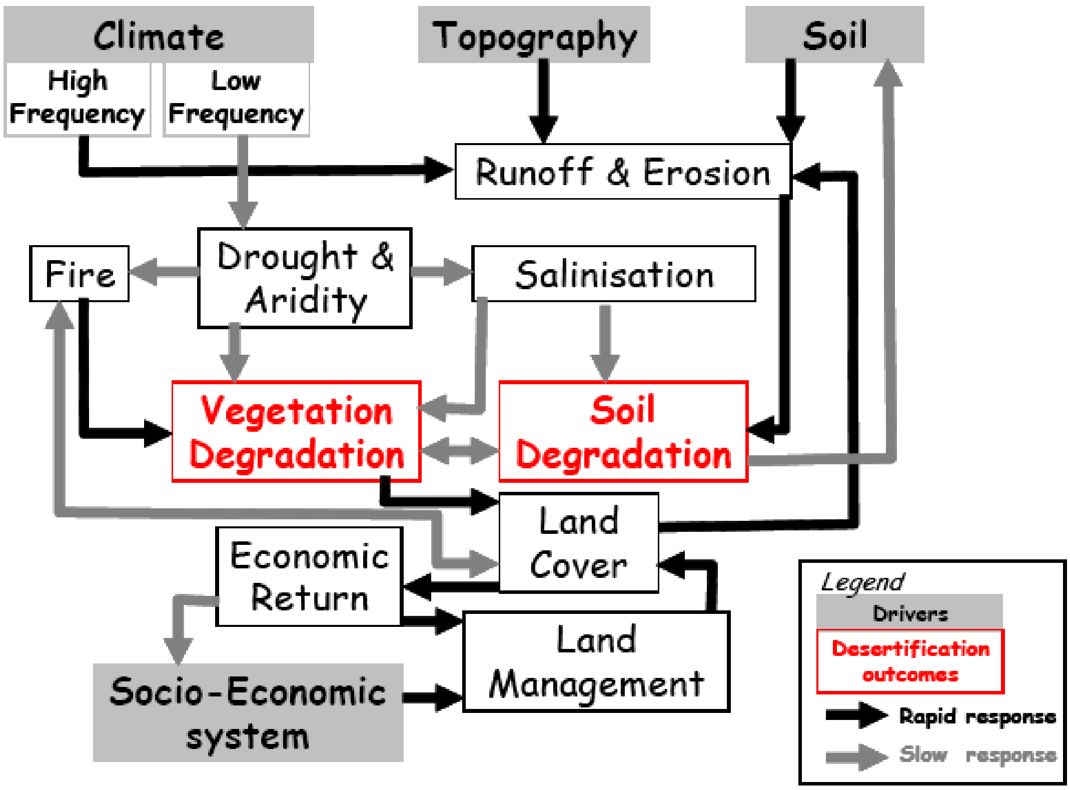

Fig. I.1: A basic conceptual view of the relations between the primary drivers of change, climate, soil, geomorphology and socio-economic drivers, and the resulting changes in processes and the degradation effects on vegetation (including agricultural land use) and soil.

1.1 Goals and objectives

The first goal of DESIRE is to look at degradation and desertification processes in an integrated way, in order to review the cause and effect links and give the conservation measures a sound scientific basis. To this end a harmonised data information system will be constructed comprising all relevant scientific and socio-economic data on degradation and desertification in the partner countries, as well as available evaluation models and tools.

The second goal is to improve the definition of suitable indicators for qualitative and quantitative evaluation of the land degradation and desertification status in the selected study regions, while the third goal of DESIRE is to assess and develop promising conservation measures using a participatory approach with stakeholder groups. This will ensure that these measures are practical, acceptable and affordable by the people who have to implement them, while their effectiveness remains based on solid science.

The fourth goal of DESIRE is to evaluate mitigation and remediation measures on a larger than the local scale, using a set of spatial models and geo-information tools that permit the evaluation of both *on-site* and *off-site* effects at various scales. These models are also capable to estimate the effectiveness of conservation measures given expected future changes in climate or land use.

The fifth objective of DESIRE is to disseminate the results, guidance and decision support tools in suitable formats for all relevant stakeholders. Although the last objective, special attention will be

given to it right from the beginning as it is crucial for the transfer and use of the knowledge gained through the course of the project.

The DESIRE Integrated Project proposed within the framework of the EU Global Change and Ecosystems Programme directly addresses the objectives of Area IV.1 “Mechanisms of desertification”, and specifically focuses on Priority area IV.1.1. “Combat land degradation and desertification”. The approach followed will be multidisciplinary and integrative, with the intention to develop a global approach for preventing and combating degradation and desertification processes on local and regional scales, in close cooperation and consultation with land users and other related stakeholders using advanced participatory, monitoring and modelling techniques. More specifically, DESIRE intends to contribute to the following scientific and technical objectives of the Global Change and Ecosystems Priority IV.1.1:

- Increasing the knowledge base and development of alternative concepts, methodologies and actions for the protection and restoration of fragile ecosystems in close cooperation with multi-stakeholder platforms;
- Field trials of land degradation indicators and strategies to mitigate or remediate degradation, and demonstration of best practices;
- Evaluation of the efficiency of existing and alternative mitigation and adaptation techniques for the protection of land from technical, social and economic perspectives;
- Development of a harmonised data information system;
- Production and dissemination of manual-style decision support systems, incorporating methodological approaches, best practices and policy relevant material for combating land degradation and desertification;
- International cooperation with the relevant regions affected by land degradation and desertification inside and outside Europe;
- Technology transfer through the development of a worldwide knowledge network to share experience, knowledge and best practices against land degradation and to find viable solutions for local or regional specific conditions;
- Cross-linkages between the DESIRE IP and relevant on-going projects, and existing networks and initiatives, such as GEO, DESURVEY, RECONDES, SCAPE, WOCAT, DIS4ME, REDMED, DESERTSTOP, DESERTLINKS, REACTION, and CLEMDES.

Besides addressing the scientific and technical objectives of the Priority area, DESIRE will also contribute to wider societal and policy objectives through:

- Minimisation of land degradation and desertification in southern European, and similar “hotspots” elsewhere in the world, thereby improving the status of the environment, biodiversity, and the quality of life for those who live there;
- Protection of employment by reducing the vulnerability of land use systems to degradation and desertification and associated job losses;
- Widening the livelihood prospects and options for people, communities, and regions, including the possible participation of SMEs in sustaining the environment;
- Reversing the outflow of inhabitants from land degradation and desertification “hotspot”, which is essential to combat desertification;
- Raising awareness amongst and increasing cooperation with local stakeholders and end-users, such as land owners, authorities, NGOs, farmer organisations, policy makers, scientists, and the general public.

1.2 Added value and potential impact of DESIRE

A number of EC-funded projects over the last 15 years have contributed to the scientific knowledge of desertification processes (e.g. MEDALUS, RECONDES), and have made some progress in modelling both the relevant bio-physical interactions and the relationship with land use decisions. Across the northern Mediterranean, and at a number of sites in North Africa, a number of field sites have been established, some of them with ten years or more of continuous data collection, and much of the data from these sites are available through project archives. There has also been considerable progress in the analysis of remotely sensed data (e.g. GEORANGE, MODEM, CAMELEO, LADAMER) to detect the state, and changes in the state, of vegetation cover in semi-arid areas, and there is considerable scope to make use of past and current projects (particularly DESURVEY) to extend results to wider areas. A third area of successful research is in the enumeration and evaluation of indicators (e.g. MEDACTION, DESERTLINKS) which provides one basis for further work in this area.

This research has generated important data, methodologies and models, which have been instrumental in deepening the understanding of the physical and human causes and effects of land degradation and desertification in Europe and the world. Many research projects have made ‘scientifically based’ suggestions and recommendations, on ways to mitigate, stop or reverse the process of land degradation. However the output has tended to be too fragmented for practical policy-making (Engelen, 2003). Various recent (e.g. MEDACTION, DESERTLINKS, LADAMER) and current (e.g. DESURVEY) projects have been making considerable progress in developing instruments that are of direct use for policy-makers, planners and managers in the affected areas and DESIRE is able to benefit from the integration of this work in the focus of combating desertification, through a combination of the most successful methods.

The DESIRE IP is designed to develop recommendations and options for the prevention and remediation of land degradation and desertification on the basis of the latest scientific achievements in soil science, ecology, agronomy, hydrology, social science, economics, and eco-technology, cross-linked with local available knowledge. The project provides a fully integrated approach to deal with land degradation and desertification problems at local and regional scales, with cooperation, consultation and interaction of a variety of end-users and stakeholders using advanced participatory, monitoring, and modelling techniques. The research outputs will serve audiences at various levels ranging from the scientific community to practitioners, agricultural extensionists, governmental authorities, policy makers, NGOs, land users, land owners, and local communities.
Potential impacts of DESIRE include:

- Reinforcing competitiveness between industry and agriculture;
- Solving societal and economic problems;
- Innovation resulting form the integration of scientific and traditional knowledge at different levels;
- Exploitation and dissemination approaches including training, direct dissemination into the international scientific community, exploitation of new potential applications and integration of results in ‘best management practices’ for land managers;
- Contribution to standards, policies and regulations;
- Coordination with other activities at national, European and international level;
- Increase the capacity of the European Research Area (ERA) in the field of sustainable development and management of natural resources.

1.3 Project outline
The DESIRE project encompasses a set of 18 so called "hotspot areas", or study sites, around the globe (section 2: Geographical context) that are affected by one or more desertification related problems. These areas have a different socio-economic context in the form of land use and land management and a different physical context in the form of climate and landscape. This gives DESIRE a truly global "laboratory" to apply both tested conservation and remediation measures, and find new and innovative approaches to combat desertification. One of the main challenges will be to merge the results into a methodological framework and harmonized database information system. This calls for a well-structured approach.
In order to achieve the goals mentioned above, the DESIRE IP has been divided into a logical series of interrelated Working Blocks (see Fig. I.2), each with specific goals, tasks and deliverables.

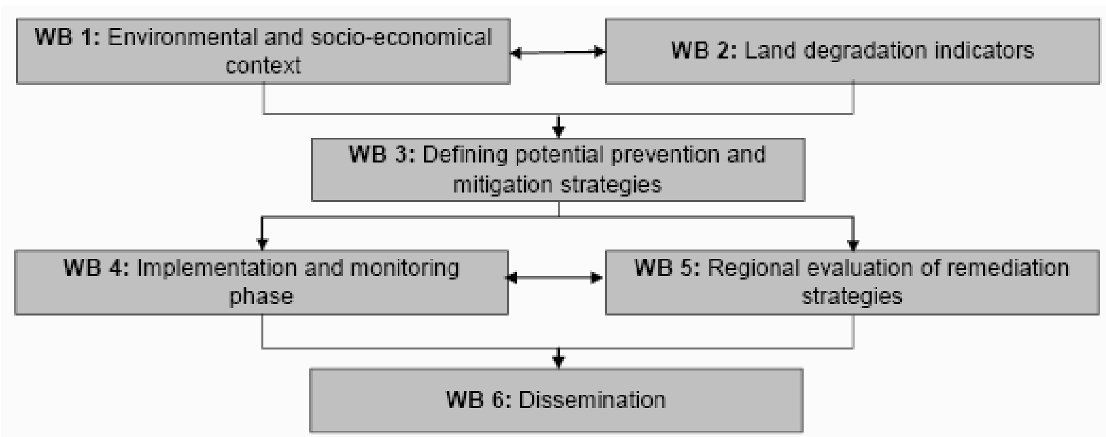

Fig. I.2: Set –up of DESIRE project in 6 interrelated Working Blocks.

WB1 inventories the 18 hotspot target areas and organizes both spatial environmental data and socio-economic data of stakeholder groups. WB2 uses this information and available results from other EU projects (see Appendix II) to define and evaluate sets of desertification indicators. These indicators are tested for their efficiency in the monitoring phase in WB4 and used to organize the monitoring results into a framework. WB3 uses the information of WBs 1 and 2 to develop a series of conservation and remediation strategies in close cooperation with the stakeholders. These strategies are implemented in each of the hotspot areas in WB4 and their efficiency is measured and modeled over the course of several years. The goal of WB5 is to upscale the results of WB4 and model them on a larger scale, forecasting regional effects of combating desertification both in environmental and socio-economical terms. WB6 finally runs parallel to the other working blocks in that it designs a harmonized data information system to which all WBs contribute data, and organizes the dissemination of the results.

2. Geographical context

The DESIRE consortium is composed of 28 partners form 20 countries. 18 Study sites around the world are selected, that are affected by one or more desertification related problems. They have a different socio-economic context in the form of land use and management, and a different physical context in the form of landscape and climate. An overview of the locations of the study sites can be seen in Fig. 1.4. In Table I.1, the main problem of desertification is given for each study area. In section 3, a more detailed overview of the specific problems in the study sites is given.

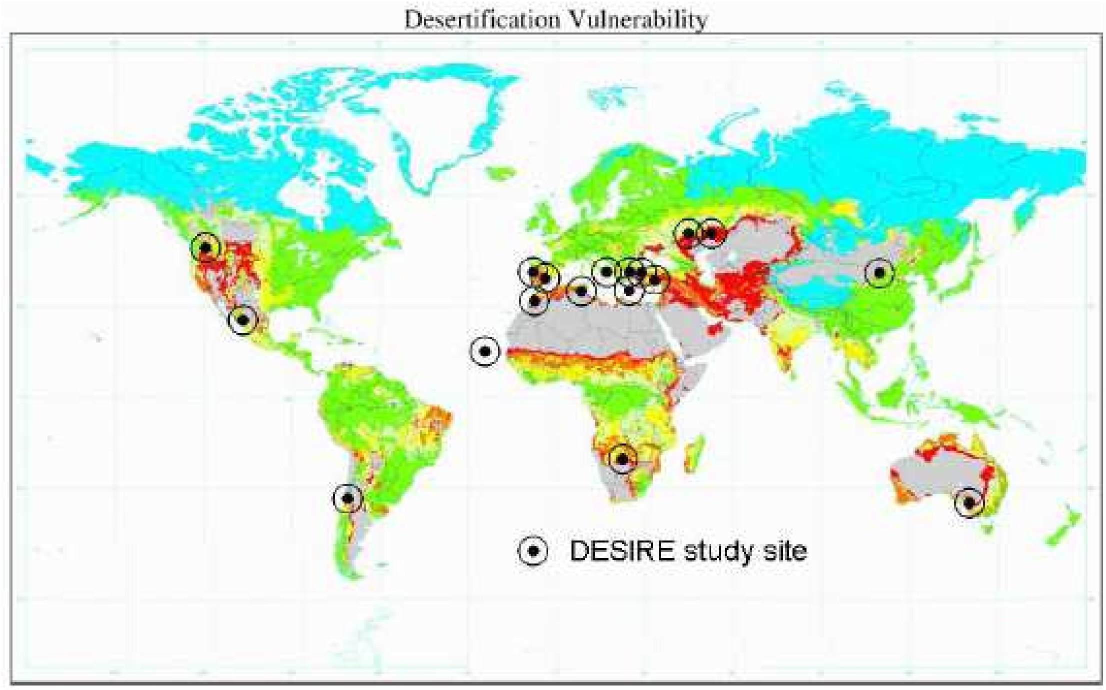

Fig. I.3: Overview of DESIRE study sites around the world.

Table I.1: Short description of main problem per study site.

Study site / hotspot	Main problem / desertification process
Guadalentin Basin, Murcia, Spain	Drought, soil erosion by water
Mação, Portugal	Forest fires
Rendina Basin, Basilicata, Italy	Soil erosion by water
Crete, Greece	Soil erosion by water, overgrazing, water stress
Nestos Basin, Maggana, Greece	Salinization
Konya Karapinar Plain, Turkey	Soil erosion by wind
Eskisehir Plain, Turkey	Soil erosion by water
Mamora / Sehoul, Marocco	Increasing pressure due to urbanization nearby
Zeuss-Koutine, Tunisia	Competition for scarce water resources
Djanybek, Russia	Poor vegetation growth
Novij, Saratov, Russia	Salinization
Loess Plateau, China	Soil erosion by water and wind
Boteti Area, Botswana	Overgrazing and decreased flooding
Cointzio catchment, Mexico	Soil erosion by water
Walnut Gulch Watershed, USA	Vegetation change, flash floods
Glenelg Hopkins region, Australia	Salinization and sporadically bush fires
Secano Interior, Chile	Soil erosion by water, extensive gullying
Santiago Island, Cape Verde	Soil erosion, drought, flash floods

3. DESIRE hotspots

In this section, the 18 DESIRE hotspots are described briefly and the specific problems are discussed in each hotspot. They are listed in alphabetic order of country. An overview and synthesis of the problems in all hotspots is given in Chapter 3.4.

Australia: Glenelg Hopkins Basin, Victoria

Secondary dryland salinity is a problem in much of Australia. The conceptual model implies a link between land clearance for agriculture and the onset of this secondary salinization. The annual crops and pastures that have replaced the cleared native vegetation have a reduced long term water use due to their shallower rooting depth and seasonal growth pattern. The Glenelg Hopkins catchment is an important regional watershed, covering about 2.6 million ha. The region has a Mediterranean climate with hot, dry summers and cool, wet winters. Mean annual rainfall ranges from 500 – 910 mm. The underlying groundwater basins are a valuable source for irrigation, stock, industrial and domestic supplies. Less than 13% of the original vegetation remains and anthropogenic changes in the landscape have led to decreasing surface water quality through increased salinization, nutrient enrichment, sedimentation and invasion of pest flora and fauna. It is estimated that 27,400 ha of land is affected by dryland salinization and the region is considered to be one of the areas most at risk from rising water tables and dryland salinity.

Botswana: Boteti area

This area has been the focus of many projects to combat desertification and it was identified as desertification hotspot and area of extreme human-induced wind erosion by these projects. The site is located in north-central Botswana which is a sparsely populated, semi-arid country. Mean annual rainfall in the area is 350 mm with a high variability. Subsistence agro-pastoralism is the dominant livelihood source. Droughts are endemic in the area and the perception of the local people is that climate has become drier and land degradation is largely due to the severe droughts and the assumed desiccation. Correcting this perception is one of the major challenges for the implementation of sustainable remediation and rehabilitation measures.

Cape Verde: Santiago Island

Cape Verde Islands receive very limited amounts of rainfall, mostly less than 100 mm. Santiago Island, the biggest and most densely populated, is packed with soil conservation structures which help to manage the fragile ecosystems. The risk of soil erosion is very high, as all soils available are used for agriculture, regardless of their slope angle, aspect or quality. High erosion rates occur during heavy rainfall events. They are also closely related to agricultural practices. Efforts to reduce soil erosion include afforestation, mechanic structures (terraces, dikes) and biological structures. The archipelago, consisting of 10 islands, is of volcanic origin. The islands closer to the African Coast are mainly flat, while the others are all mountainous. The economy suffers from a very poor natural resource base, including serious water shortages due to cycles of long-term drought.

Chile: Secano Interior
Due to the topographic conditions and rain intensity and distribution, water erosion is the most important form of soil degradation in Chile, particularly in the unirrigated area in central Chile (‘secano interior’). Most of these 2 million ha is occupied by a traditional agricultural system which combines livestock activities with the production of cereals. There are three main soil types in the region, which are all acidic (pH 5.8 – 6.2), highly susceptible to erosion and characterized by chronic deficiencies in organic matter, macro- and microelements. Average annual rainfall is 650 mm, concentrated in June and July with a 5-months dry season. High levels of run-off occur from the structurally degraded and compacted soil surface. The depressed agricultural state is due to past overexploitation by large landholders. Vegetation is, except where irrigated, thoroughly invaded by the spiny legume tree *Acacia caven*, locally known as ‘espino’. Introduced herbivores such as cattle, sheep and rabbits, contribute to maintaining the region in its present degraded state.

China: Loess Plateau
This area is well known for its deep loess deposits and serious soil erosion. The average soil loss is 3720 tons/km^2/year. Every year about 0.01 – 2 cm topsoil is washed away, which is partly due to the semi-arid climate of the region. The Plateau is located in the middle reaches of the Yellow River. Cultivation started 6000 years ago and during the last few centuries, especially the last hundred years, natural vegetation is destroyed because of increasing population and inappropriate land use. Grass cover in most of the land is less than 50%. During the last 50 years, about 150,000 km^2 of eroded land has been controlled by various conservation measures. The average annual rainfall of the region is 250 – 700 mm, concentrated in summer. The landscape consists of loess hills and loess tableland with a gully density of 4-6 km/km^2.

Greece: Crete
The eastern and central part of Crete is already badly degraded while the rest is highly sensitive to desertification. The major land degradation processes are soil erosion, collapse of terraces, overgrazing, salinization in the lowlands due to poorly drained soils and overexploitation of groundwater. Natural vegetation was cleared for agriculture, but soil conservation measures were insufficient and these areas are severely degraded. Forest fires and overgrazing further destroyed the natural vegetation and prevented regeneration leading to unproductive, sparsely populated and desertified areas. On the island, a gradient in rainfall is experienced with annual means between 400 mm in the coastal areas to 1100 mm in the upper mountainous area. Soils are formed on a variety of parent material, with soils on marl, conglomerate and alluvial deposits being relatively deep (>75 cm) while soils on shale and limestone are shallow to moderately deep. Most slopes have gradients steeper than 18%. Soil erosion occurs at large rates in the past 50 years following intensification and mechanization of olive cultivation and vineyards and overgrazing of rangeland. This resulted in badland formation and many uplands have been terraced. Tillage affects hillslopes very adversely, so limited tillage and terracing is recommended but these land management practices are not yet extensively applied since farmers are not yet convinced of the efficiency of these practices on crop production and land protection.

Greece: Nestos Basin, Maggana
In the Nestos River Delta Plain in the Thrace region, Greece, a variety of flood-controlling engineering works have been built. These measures were carried out without any provision for the induced changes in the ecological balance and they have caused a decrease of groundwater recharge from surface water sources. At the same time, water demand increased due to increase in cultivated area. The problems arising from these developments include a gradual disappearance of coastal wetlands and salinization. The construction of several drainage works and the increasing use of irrigation water have resulted in seawater intrusion and deterioration of groundwater quality. EC measures revealed severe salinity with values >8000 μS/cm. Further from the sea, groundwater EC varied between 2000 – 3000 μS/cm. The causes of salinization in the coastal area of Xanthi are:

- low precipitation, increased during dry periods;
- irrigation with saline water and problematic soil drainage;
- shallow groundwater table with high salt content.

Italy: Rendina Basin, Basilicata
The study side contains the hillslopes of the artificial Rendina reservoir, created in the 1950s to satisfy the agricultural water needs in the downstream area. Sedimentation rates in the lake have been high, so that after 20 years the sediments had to be removed. On the hillslopes, deep and isolated rills as well as badland-type erosion, extensive rill erosion and piping are found. The rills develop into small gullies in winter and landslides occur along the slopes. Triggering factors for high rate erosion processes include poor care for the environmental impact of artificial reservoirs in the planning phase, the use of inadequate agricultural techniques, deforestation and intentional fires. The main type of erosion (water erosion) is due to very long dry seasons and short wet periods in which all rainfall is released and the widespread occurrence of very fine erodible Tertiary and Quaternary sediments. Annual precipitation is about 580 mm.

Mexico: Cointzio catchment
In Mexico, about 80% of the country shows some degree of erosion. Michoacán, with 2 million ha affected by severe erosion, is the state with the largest erosion problem. In 1980, 71% of the state territory was affected by erosion and since then deforestation rates and livestock raising increased, leading to even larger erosion problems. The Cointzio catchment is representative since it experiences all problems: soil erosion, deforestation, overgrazing etc. Water quality is also a concern in the area. The Cointzio catchment is located in an area with active volcanoes, which are separated by small valleys. Soils are of volcanic origin: high locations have Andosols, on the slopes Acrisols predominate and in the plains Vertisols and Luvisols are found. After erosion of these soils, a layer of volcanic tuff called tepetate is often present, inhibiting by its chemical and physical characteristics the regrowth of natural vegetation. The climate is sub-humid with heavy rains in summer; average precipitation is 700 – 900 mm, mainly from June to October. Land use consists of forests, agricultural land, fallow fields and eroded and desertified areas. Deforestation rates are high and grazing is practiced on fallow fields, increasing erosion.

Morocco: Mamora Forest and the Sehoul Plateau, Rabat region
As has been said, the region is affected by desertification processes already. These include the poor conditions of the cork oak forest due to overgrazing, wood cutting and forest diseases; the retreat of the forest off old dune soils, which creates conditions for desertification. Problems that are directly or indirectly related to urban growth in the surrounding are the need for space for activities and transport from the city; the increasing pressure over the natural resources (soil and water) by a more intense agricultural system which is adopted to answer the proximity of the Rabat urban market; and the deficit of water and the competition between agriculture, urbanization and tourism.
In the area, land use consists of rain fed wheat and maize, horticulture, figs and remnants of cork oak forest. Its climate is typically Mediterranean with annual rainfall of 400 – 550 mm mainly during the end of autumn, winter and early spring. In the forest the main problem is the weakness of the sandy soil and the rapid retreat of the vegetation cover. Also, sheet erosion and gullies and aeolian remobilisation are problematic. No significant counter-degradation measures are undertaken and the impact of the nearby increasing urban pressure is expected to sharply increase degradation and desertification processes.

Portugal: Mação
This area is one of the four UNCCD pilot areas in Portugal. It has undergone severe drought periods that completely changed the region. Catastrophic forest fires burned most of the municipality forest area down to ashes. Some areas were burned twice in 5 years, leading to severe soil and vegetation degradation. Mação is situated in the transition zone between the Atlantic and Mediterranean climate types. Average annual rainfall decreases in a 20km transect from 1000 mm in the north to less than 600 mm in the south. Recently, several drought years occurred. Soils are typically very shallow and stony humic cambisols. Problems include, apart from forest fire, bad agricultural and forestry practices, such as ploughing from top to bottom on slopes. After massive migration towards Lisbon in the 1950s and 1960s, major changes in land use led to shrub and forest increase and subsequently to their degradation through fires.

Russia: Djanybek, northern Caspian region
Djanybek is located in the southeast of European Russia with regional-scale degradation of natural, agricultural and irrigated lands. The northern Caspian region is characterized by a dry continental climate with mean annual precipitation of 298 mm of which almost half falls during the warm period (April – September) when monthly evaporation reaches 900 – 1000 mm and maximum day temperature

is >40°C. A stable snow cover exists from November to March. The area is a closed plain almost lacking drainage with large mesodepressions and pronounced microrelief, and is composed of thick slightly saline heavy loams. Mineralization of the groundwater and soil salinity are problems which occur in solonchaks, solonetz and light-chestnut soils occupying the microhills and slopes. These salt-affected soils can not be used for afforestation and cultivation without preliminary amelioration.

Russia: Novij, Saratov, Volga Basin
As a result of active development of irrigating systems in the Volga region in the 1960-70s, the natural water balance has changed in significant areas. A rise of the water table to the root zone led to salinization, if these contained salts. In the 1990s, irrigation was stopped on about half of the formerly irrigated lands. In the study area (the joint-stock company 'Novij'), average annual rainfall is 366 mm, while average annual evaporation is 660 – 780 mm. In 1965, irrigation started. At the time, groundwater depth was about 15 – 20 m and the soil was basically not salted. Irrigation rates increased to about 2500 – 4500 m^3/ha and in the early 1980s, subsoil water levels had risen to 2 -3 m, and to 1-2 m in depressions. In the beginning of the 1990s, irrigation was stopped on part of the area and some fields were taken out of production. On fields where irrigation continued, subsoil waters have continued to rise. The cause of salinization problems in this area is the rise of the groundwater level due to over-irrigation in previous years.

Spain: Guadalentin Basin, Murcia
In this area land degradation phenomena can be readily observed, such as soil erosion by rills and gullies. These are due to very frequent tillage, fallow land and land abandonment in a semi-arid climate with rains of high intensity. Also, some rock types very susceptible to erosion exist in the area. Measures to combat these problems have been applied for over 100 years, but they have been only partially successful. The Guadalentin is an ephemeral river for most of its course. Annual precipitation ranges from <300 to over 500 mm, annual potential evapotranspiration rates of 1000 – 2000 mm are common and droughts commonly last for 4 -5 months. Land uses include almonds and herbaceous crops under dryland conditions and citrus and greenhouse under irrigation.

Tunisia: Zeuss-Koutine Watershed
This watershed is located in south-eastern Tunisia, covering around 1000 km^2. The traditional land use system in this area combined a concentration of production on limited areas with pastoral use of a large area. During the last forty years, however, production systems have changed rapidly. After the privatization of tribal lands, the development of irrigated crops and industry and a fast extension of fruit tree orchards at the expense of natural grazing lands occurred. As a result, natural resource exploitation increased with the exploitation of groundwater aquifers by drillings for these new land uses and a competition for the access to these natural resources and for land ownership was created. The climate is Mediterranean with the warmest period in June to August, when temperatures can reach 48°C. Rainfall is characterized by low averages, high irregularity and it torrential nature. Potential evapotranspiration is very high. Soils are mainly regosols on soft rock and lithosols on hard rock. Agricultural systems in the study area are distinguished by: the development of arboriculture and the extension of cultivated fields at the expense of rangelands; gradual transformation of livestock husbandry from the extensive mode to the intensive mode; and the development of irrigated agriculture exploiting the surface and deep aquifers. From the 1960s, the region experienced serious anthropogenic pressure, resulting in a accelerated rate of degradation of the natural resources. Other problems include poor vegetation cover, poor and loose soils, water erosion, wind erosion, overgrazing of rangelands, extension of cropping areas on unsuitable lands and interest conflicts between upstream and downstream users.

Turkey: Eskisehir Plain
The Eskisehir area is one of the most severely eroding areas in Turkey, due to a combination of relatively high tectonic activity, lack of significant natural plant cover and torrential rainfall. Eskisehir city has important agricultural activity and many industrial complexes and the economic significance will increase in the coming years. The region is characterized by a dry continental climate with annual precipitation of 380 mm. Almost half of rural area is used for agriculture, a fourth is occupied by meadows and the remaining by forests. The sensitivity to erosion of wide agricultural areas and the expected strong drought as well as he dependence of agriculture to rapidly polluting surface and groundwater necessitates an integrated approach.

Turkey: Konya Karapinar Plain

The Konya region is situated in the south of Central Turkey where annual precipitation is lowest in the country (320 mm). Rainfall occurs in summer and autumn and is of torrential nature. In parts of the area, sand dunes have been formed in 50 years due to wind erosion caused by a lack of land management under near desert conditions. The region constitutes the most accelerated desertification zone. Soils are very limey and have high salt contents. Land use consists of cereals in dry areas and sugar beets and various fruit plantations where water is available. Erosion mitigation efforts started in the 1960s and have been directed against wind erosion. Significant results were obtained by physical protection and education of land-users. However, due to a lack of full understanding of erosion processes, the results are not fully successful.

USA: Walnut Gulch Experimental Watershed, Arizona

This area represents the climatic, hydrologic and land use conditions of a very large area and is considered to be the most intensely monitored semi-arid watershed in the world. The area is thought to have been mostly grassland 100 years ago, while now grassland occupies only one third of the land area. No specific reason or cause is given for this change in land use or land cover. It has led to a change in hydrologic and sediment delivery conditions. In this diverse, yet fragile area drought conditions will lead to further loss of the vegetative cover. Primary land use is cattle grazing, with mining, limited urbanization and recreation making up the remaining uses. A primary concern of customers, stakeholders and partners is to accurately quantify and manage the soil and water resources to support people, agriculture and the environment.

Appendix II: Previous and ongoing projects

As has probably become clear, there are very many projects that deal with desertification or related issues. Many of these are EU-financed, but also smaller, local projects exist. Here, only the larger projects are listed, which resulted in a total of 48 projects being reviewed. Each project is described in a standardized way, including full name of the project, time span, the major aim of the project, a short description of the activities and objectives and the involved countries (partners and field sites, if applicable). The project website is given for further information. In some cases, no project website existed. Possibly, websites with information about the project are given then. First, 14 ongoing projects are listed; afterwards, 34 past projects that are finished are given. In each section, projects are listed in alphabetic order of their acronym, as most projects are known by this abbreviation. A synthesis that places the projects in a broader contexts and allows comparison of projects without losing their identity is given in Chapter 1.

1. Ongoing projects

ARIDnet

Full name: Assessment, Research, and Integration of Desertification research network
Time span: 2004 - ?
Aim: The projects goal is to provide leadership for developing and testing a new synthetic paradigm for desertification.
Description: ARID*net* is research coordination network. The new synthetic paradigm for desertification, which is called the Dahlem Desertification Paradigm, is based on the simultaneous roles of the meteorological and ecological dimensions of desertification (the biophysical factors) and the human dimensions of desertification (the socio-economic factors). Activities include conducting workshops to debate the Dahlem Desertification Paradigm (DDP) - a product of the 2001 Dahlem Conference on desertification - for critical evaluation and refinement; formulating working groups to develop comparative case studies to test the DDP; conducting a quantitative synthesis of what matters in desertification, when and where it matters, and why; recruiting new researchers and stakeholders into ARIDnet so a broad-based and useful approach to desertification problems can be developed.
Countries: worldwide; partners in USA, Mexico, Honduras
Website: http://www.biology.duke.edu/aridnet/

COST 634

Full name: COST Action 634: On- and Off-site Environmental Impacts of Runoff and Erosion
Time span: 2004 - 2008
Aim: The COST action aims at coordinating and synthesising European soil erosion research in the contexts of land management and policy formulation so as to limit agricultural runoff and to improve soil conservation.
Description: This will increase agricultural multifunctionality and reduce off-site impacts of runoff and erosion. To achieve this goal, the many barriers hindering the implementation of runoff prevention and soil conservation in Europe have to be identified and analysed on all levels, including the scientific, political, administrative and management level. In simultaneously addressing different levels involved in land use decision-making and soil conservation, COST 634 participants will help to identify and solve conflicts and foster integrated solutions for soil conservation and land management that can be accepted by all interest groups.
Countries: partners in France, Germany, UK, the Netherlands, Poland, Denmark; 25 European countries signed in to the COST Action.
Website: http://www.soilerosion.net/cost634/

DeSurvey

Full name: A Surveillance System for Assessing and Monitoring of Desertification
Time span: March 2005 – March 2010
Aim: The project goal is to deliver a compact set of integrated procedures, with application and tutorial examples at the EU and national scales.
Description: In spite of the relevance of diagnosis to help the success of desertification treatment, there is a lack of standardized procedures to perform it at operational scales. This project offers a contribution to fill this gap by complementing assessment of desertification status with early

warning of risks and vulnerability evaluation of the involved land use systems. To this purpose the interactive effects of climatic and human drivers of desertification will be taken into account in a dynamic way. Fulfilling this objective requires the integration of a hard core of basic and application-oriented research, with the development of user-support technologies, capacity building, and a wide range of interfacing with other EU and international programmes, affected users and stakeholders, as well as data and technology providers including SMEs. A consortium of 39 organizations with a wide range of skills builds the project partnership.

Countries: Field sites in Greece, Spain, Portugal and Italy and the performance of DeSurvey in other areas outside Europe will be further tested against other expertise and available procedures in Maghrebian and Sahelian countries as well as in central Chile and NW China.

Website: http://www.desurvey.net/

ILTER

Full name: International Long Term Ecological Research

Time span: long term

Aims: To foster and promote collaboration and coordination among ecological researchers and research networks at local, regional and global scales; improve comparability of long-term ecological data from sites around the world, and facilitate exchange and preservation of this data; deliver scientific information to scientists, policymakers, and the public and develop best ecosystem management practices to meet the needs of decision-makers at multiple levels; and facilitate education of the next generation of long-term scientists

Description: ILTER consists of networks of scientists engaged in long-term, site-based ecological and socioeconomic research. Our mission is to improve understanding of global ecosystems and inform solutions to current and future environmental problems

Countries: no field sites. 32 countries worldwide are a member, 11 consider becoming a member

Website: http://www.ilternet.edu/

LADA

Full name: Land Degradation Assessment in Drylands

Time span: 2005 - 2009

Aim: The LADA project aims to assess causes, status and impact of land degradation in drylands in order to improve decision making for sustainable development in drylands at local, national, subregional and global levels.

Description: The project's purpose is to develop and test an effective assessment methodology for land degradation in drylands. By marshalling the extensive knowledge and varied expertise already available worldwide, by creating a new, more interactive and comprehensive framework of assessment methods, and by capacity building and testing this framework in real-world situations, LADA is putting together the pieces of a global challenge. Once the tools and the data required in order to understand the root causes, driving forces and functioning of the degradation puzzle are in place, it will be possible to assess land degradation at global, national and sub-national levels to identify status and trends; hotspots and bright spots of desertification.

Countries: Senegal, Argentina, Cuba, South Africa, Tunisia and China are pilot countries.

Website: http://lada.virtualcentre.org/pagedisplay/display.asp

LUCINDA

Full name: Land care in desertification affected areas: from science towards application

Time span: April 2006 – March 2008

Aims: The objectives of LUCINDA are to:

1) provide a concise and comprehensive information pack containing guidelines for sustainable land management in desertification-affected areas derived from the scientific results of past and on-going EU research projects;

2) make this information available to regional and local authorities who, through national participation in the UNCCD, have a specific mandate to combat desertification.

Description: During recent decades great progress has been made by the scientific community in understanding the nature and complex causes of land degradation and desertification in Europe. Despite efforts (particularly in FP5) to assemble and present the results for practical application, there is still a wealth of research results that have not been fully exploited nor made accessible to those who can benefit from them.

Countries: no field sites; 5 partner countries

Website: http://www.fcsh.unl.pt/desertification/LUCINDA/

PAP/RAC

Full name: Priority Actions Programme / Regional Activity Centre

Time span: long term

Aim: The centre's aim is to address immediate problems of a developmental nature and their effects on the coastal environment and its resources, through practical activities in several fields. The intention is to induce swift results through the use of sound environmental management practices. Importantly, coastal areas comprise not only their marine and terrestrial parts but also their adjacent river basins.

Description: The common objective is the creation of a healthier Mediterranean environment, resting on the principle of sustainable development. PAP/RAC offers technical assistance through the provision of workshops and specialist training. Thanks to a wide network of partnerships with experts, institutions and organisations, it has developed broad pan-Mediterranean outreach capabilities. It also publishes research, guidelines, technical reports and manuals as part of its core capacity-building strategy and coordinates local projects that typically involve the participation of many local bodies.

Countries: based in Croatia, 21 Mediterranean countries involved

Website: http://www.pap-thecoastcentre.org/

PROTERRA

Full name: ProTerra

Time span: (unknown)

Aim: The project's key aim is to help reduce the extreme soil losses which are occurring under conventional soil management, using practical techniques which are compatible with the cropping systems.

Description: ProTerra is a collaborative research project between academic institutions, NGO's and Industry, which has been designed to test agronomic approaches for soil and water conservation in Mediterranean perennial cropping systems (e.g. olives and vines). Generally, the approaches tested are based on the use of non-selective herbicides (e.g. glyphosate and paraquat) to manage vegetative soil cover between crop rows; the vegetative cover consisting of either deliberately sown vegetation or naturally occurring weeds. These cover crops protect and strengthen the soil, increasing their ability to resist soil erosion and absorb water. The outcomes of the approaches taken are compared with local conventional practice, which most commonly consists of soil tillage used to maintain weed free inter-rows, this tillage being the major reason for increased soil erosion risk. The approaches are compared in terms of soil erosion, water run-off and the economic consequences.

Countries: Field trials in France, Italy, Portugal and Spain, collaboration with research institutions in France, Great Britain, Italy, Portugal and Spain

Website: http://www.proterra.eu.com/

RECONDES

Full name: Conditions for Restoration and Mitigation of Desertified Areas Using Vegetation

Time span: February 2004 – April 2007

Aim: The major objective is to produce practical guidelines on the conditions for use of vegetation in areas vulnerable to desertification, taking into account spatial variability in geomorphological and human-driven processes related to degradation and desertification.

Description: The focus of RECONDES is to address the mitigation of desertification processes by the means of innovative techniques using vegetation in specific landscape configurations prone to severe degradation processes. The project will combine the understanding of the mechanisms of land degradation and of the critical soil conditions necessary for maintaining and restoring soil and land quality and ecosystem health to identify how and where vegetation could be used to mitigate desertification. It will identify the conditions or thresholds, which have to be attained or retained for vegetation growth and survival and examine where those conditions are found. It will match those conditions against the processes of degradation to identify where treatments or restoration will be most effective. It will identify innovative measures, which might be taken to create or maintain conditions. Crucially, it will examine linkages within the landscape at different scales to determine the key points for intervention.

Countries: Field site in Spain (Cárcavo catchment in the Murcia region), 6 partners from UK, Belgium, Spain, Italy and the Netherlands

Website: http://www.port.ac.uk/research/recondes/

ROSELT

Full name: Long Term Ecological Monitoring Observatories Network

Time span: long term

Aim: The fundamental purpose of ROSELT is to improve knowledge of the mechanisms, causes, consequences and scope of desertification in arid and semi-arid zones of the circum-Saharan area. Its objectives concern long-term environmental monitoring and research into the interactions between populations and their environment at local level.

Description: In spite of the quantity and quality of research work on land degradation in arid and semi-arid zones, very little research has been conducted into the dynamic links between the biophysical conditions of land degradation (including desertification) and population lifestyles. Faced with the problem of desertification, societies have for many years developed mechanisms to protect themselves against its detrimental effects the best as they can. There is a long tradition of migration of populations during the dry season, mobility of herds (the importance of transhumance), and the exploitation of extensive and highly dispersed crops to reduce economic and climatic risks, etc. This adaptive response of societies clearly denotes the existence of strong links between societies and their environment; links that are important to understand before undertaking development action or renewable resource management initiatives. Furthermore, the scientific community and research beneficiaries are faced with a serious lack of environmental data over a sufficiently extensive period of time to determine trends through reliable indicators.

Countries: 30 circum-Saharan observatories, of which 12 are pilot observatories in 11 countries (Morocco, Algeria, Tunisia, Egypt, Mauritania, Mali, Niger, Senegal, Cape Verde, Ethiopia and Kenya).

Website: http://www.roselt-oss.org/accueil.php?type=graph&langue=1

SENSOR

Full name: Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions

Time span: December 2004 – November 2008

Aim: SENSOR will develop science based ex-ante Sustainability Impact Assessment Tools (SIAT) to support decision making on policies related to multifunctional land use in European regions.

Description: The technical objective of SENSOR is to build, validate and implement sustainability impact assessment tools (SIAT), including databases and spatial reference frameworks for the analysis of land and human resources in the context of agricultural, regional and environmental policies. The scientific challenge is to establish relationships between different environmental and socio-economic processes as characterised by indicators considered to be quantitative measures of sustainability. Scenario techniques will be used within an integrated modelling framework, reflecting various aspects of multifunctionality and their interactions. The focus will be on European sensitive regions, particularly those in accession countries, since accession poses significant questions for policy makers regarding the socio-economic and environmental effect of existing and proposed land use policies.

Countries: The consortium includes 33 partner institutions from 15 European countries and 6 partner institutes from China and South America

Website: http://www.sensor-ip.org/

Sustainable Uplands

Full name: Managing Uncertainty in Dynamic Socio-Environmental Systems: an application to UK uplands

Time span: 2006-2009

Aim: To help people in uplands better anticipate, monitor and respond to future change

Description: Building on previous research in Botswana, this project developed a methodological framework that was adapted for the DESIRE project. Focussed on land degradation in UK uplands, the aim of the project is to combine knowledge from local stakeholders, policy-makers and social and natural scientists to anticipate, monitor and sustainably manage rural change. It does this through a combination of stakeholder participation and integrated modeling.

Countries: The project is a collaboration between the Universities of Leeds, Durham, Sheffield and Sussex together with the Moors for the Future partnership and Heather Trust. It is funded by the UK Government Research Councils with Defra and SEERAD, and has study sites in the Peak District National Park, Yorkshire Dales and Galloway, Scotland.

Website: http://homepages.see.leeds.ac.uk/~lecmsr/sustainableuplands/

WOCAT
Full name: World Overview of Conservation Approaches and Technologies
Time span: ongoing, since 1992
Aim: WOCAT's mission is to provide tools that allow Soil and Water Conservation (SWC) specialists to share their valuable knowledge in soil and water management, that assist them in their search for appropriate SWC technologies and approaches, and that support them in making decisions in the field and at the planning level.
Description: Every day land users and soil and water conservation (SWC) specialists evaluate experience and generate know-how related to land management, improvement of soil fertility, and protection of soil resources. Most of this valuable knowledge, however, is not well documented or easily accessible, and comparison of different types of experience is difficult. This SWC knowledge therefore remains a local, individual resource, unavailable to others working in the same areas and seeking to accomplish similar tasks. This may be one of the reasons why soil and water degradation persists, despite many years of effort throughout the world and high investments in SWC. WOCAT was established as a global network of SWC specialists. It facilitates more efficient use of existing know-how and, consequently, of development funds. It thus helps to optimise the implementation of appropriate SWC and to avoid duplication of effort.
Countries: As a network, WOCAT has a list of collaborating and funding institutions (see website).
Website: http://www.wocat.net/

WWAP
Full name: World Water Assessment Programme
Time span: long term
Aim: This UN-wide programme seeks to develop the tools and skills needed to achieve a better understanding of those basic processes, management practices and policies that will help improve the supply and quality of global freshwater resources.
Description: The WWAP, building on the achievements of the many previous endeavours, focuses on assessing the developing situation as regards freshwater throughout the world. The primary output of the WWAP is the periodic World Water Development Report (WWDR). The Programme will evolve with the WWDR at its core. Activities include data compilation (geo-referenced meta-databases); supporting information technologies; data interpretation; comparative trend analyses; data dissemination; and methodology development and modelling.
Countries: global, listed on their website
Website: http://www.unesco.org/water/wwap/

2. Past projects

AIDCCD
Full name: Active exchange of experience on indicators and development of perspective in the context of UNCCD.
Time span: February 2003 – June 2006
Aim: The AID CCD project aims at developing and coordinating exchanges of experiences within scientific institutions involved with UNCCD, focusing on "scientific and technical aspects of desertification benchmarks and indicators and remote sensing"; elaborating a review on the use of indicators and benchmarks in the different annexes, with specific references to the response on impact indicators adopted in the NAP within UNCCD; identifying core problems related to indicators to identify future needs to improve UNCCD implementation.
Description: The project addresses the issue of the implementation of the UNCCD in a global perspective, by involving all regional Annexes. In all Annexes, desertification benchmarks and indicators, prevention and mitigation activities and the information circulation systems have been recognised as priority issues and much work has been carried out so far to address them. However, due to a lack of exchange of information among Annexes, these issues have been developed in parallel, producing a relevant quantity of data and information that has never been organised systematically. To achieve the objectives above, two thematic seminars will be realized. These constitute the core activities of the project. Their purpose is to draw up the state of the art, to stimulate exchanges of experience and to identify development perspectives. This should lead to the final objective: showing in a qualitative and whenever quantitative way how science and technology can be used to assist decision makers in mitigating desertification in a sustainable development perspective.
Countries: worldwide; partners in Italy, France, Tunisia, Burkina Faso, Namibia, China and Argentina

Website: http://nrd.uniss.it/sections/aid-ccd/index.htm

ASMODE

Full name: Assessment of remote sensing techniques for monitoring the extent and progression of desertification in the Mediterranean area

Time span: June 1992 – September 1994

Aim: To assess the potential of remote sensing techniques and GIS for the purpose of studying, monitoring, and possibly controlling the dynamics of desertification in the Mediterranean area and as well to close the "scale gap" between site experiments of energy and water exchange at the earth surface, and the desertification processes taking place at national to regional levels.

Description: Data of several satellite-sensors (NOAA-AVHRR, METEOSAT and LANDSAT) are researched on their usefulness for the monitoring of desertification. Two approaches to monitor desertification are followed in the project: (1) The energy and water balance approach to monitor vegetation activity. Satellite measured land surface temperatures and albedo's are used to estimate aridity parameters like net radiation, actual evapotranspiration, and rainfall. (2) The direct monitoring of the vegetation cover using the vegetation index. The project consists of a one-year monitoring experiment generating satellite derived datasets of Spain to be analyzed in connection with field survey data and existing datasets in a GIS.

Countries: partners in the Netherlands and Spain

Website: seems not to exist.

CAMELEO

Full name: Changes in Arid Mediterranean Ecosystems on the Long term and Earth Observation

Time span: March 1998 – June 2001

Aim: The objective of the project is to develop a comprehensive method for monitoring desertification in the south of the Mediterranean basin, which provides information useful for the operational management of arid lands and which involves all the affected countries.

Description: The main purpose is to discriminate, at local scale, (and after elimination of seasonal fluctuations) areas where soil and vegetation are degrading, where they are stable, where they are recovering (e.g. after restoration action has been taken). In addition, the understanding of the relationships between those changes and land use will be a major objective. This aim is an answer to the need for reliable and detailed data on the condition and evolution of arid zones as has been strongly expressed by officials in charge of environmental policies. Desertification in the northern shore of the Mediterranean is already a concern at the European level. The southern shore is far more affected because of the dryer climate, the inherent fragility of the ecosystems and high demographic pressure.

Countries: Field sites in Morocco, Algeria, Tunisia and Egypt; partners in France and Italy.

Website: http://www.medaqua.org/forum/CAMELEO.html, project website (www.egeo.sai.jrc.it/cameleo) is not working.

CLEMDES

Full name: Clearing house mechanism on desertification for the northern Mediterranean region

Time span: November 2002 – April 2005

Aim: The project aims to set up an internet based network devoted to the improvement of the diffusion of information.

Description: The countries of the Northern Mediterranean region are affected by desertification and for this reason they have prepared national and regional action programmes. One of the priorities identified in these programmes is the diffusion of information among the public. The present project aims to set up an internet based network devoted to the improvement of the diffusion of information. The establishment of an internet based tool will decentralize existing information using the national language. The project aims to identify a common format and terms of reference for the setup of a Mediterranean portal and of national Internet based information facilities. Two workshops are planned for the identification of priorities and the presentation of results at international level. At national level meetings will be organized to involve the various stake holders and collect information and data to be diffused through Internet.

Countries: partners in Italy, Greece, Israel, Portugal, Spain, Turkey

Website: project website (www.clemdes.org) not working

CLIMED

Full name: Effects of climate change variability in water availability and water management practices in western Mediterranean

Time span: March 2001 – May 2004

Aim: The main objective of the CLIMED project is to provide information on the foreseeable climatic changes in the Western Mediterranean.

Description: This will be done through a multiple approach which includes field hydrological databases, together with statistical models and physically based models, performing an evaluation on how fresh water resources will vary. The project addresses evapotranspiration of different land uses, by measuring catchments runoff at small catchments, and performs up scaling through statistical methods directed to the analysis of extreme events, through the use of LISEM model. CLIMED has an important socio-economic dimension, which relates the socio-economic data with the information provided by the climate and hydrological stages, in order to produce, for the selected river catchments, an assessment of the impacts of changes on water availability. Another major goal is to build a conceptual model based on integrated management methodologies, defining guidelines to support decision-making processes and strategic paining for water resources, as well as defining policy recommendations based on combined top-down and bottom-up approaches.

Countries: partners in Portugal, Morocco, the Netherlands and Tunisia, study sites in Portugal, Morocco and Tunisia

Website: http://www2.dao.ua.pt/RECNATUR/climed/

CORINE

Full name: Coordination of information on the Environment

Time span: long term (from 1985 onwards)

Aim: The three aims of the project are (1) to compile information on the state of the environment with regard to certain topics which have priority for all the Member States of the Community, (2) to coordinate the compilation of data and the organization of information within the Member States or at international level, and (3) to ensure that information is consistent and that data are compatible.

Description: If our environment and natural heritage are to be properly managed, decision-makers need to be provided with both an overview of existing knowledge, and information which is as complete and up-to-date as possible on changes in certain features of the biosphere. In order to determine the Community's environment policy, assess the effects of this policy correctly and incorporate the environmental dimension into other policies, we must have a proper understanding of the different features of the environment, including the state of the individual environments; the geographical distribution and state of natural areas and of wild fauna and flora; the quality and abundance of water resources; land cover structure and the state of the soil etc.. A further objective of the CORINE programme is to bring together all the many attempts which have been made over the years at various levels (international, Community, national and regional) to obtain more information on the environment and the way it is changing.

Countries: Land cover data for most EU15 countries and 12 central and eastern European countries and coastal zones of Morocco and Tunisia.

Website: A project website does not exist, information can be found on http://www.eea.europa.eu/ and their 1990 brochure is available at:
http://terrestrial.eionet.europa.eu/CLC2000/docs/publications/corinescreen.pdf.

DEMON-I

Full name: An integrated approach to Mediterranean land degradation mapping and monitoring by remote sensing

Time span: July 1992 – December 1994

Aim: The objectives are to develop and validate methodological procedures for extracting vegetation and soil surface parameters from remotely sensed data for monitoring changes and trends in areas submitted to land degradation and to develop a GIS oriented approach to erosion hazard modelling and mapping.

Description: The field and laboratory measurements will focus, concerning respectively vegetation and soil, on Leaf Area Index, optical properties of leaves, ground checks concerning vegetation mapping, water and chemical content and soil emissivities(box method), soil temperatures (infrared radiometers), soil sample analysis. Major research topic will be the detection and quantification of low amounts of green or dry vegetation (estimation of percent vegetation cover or LAI) and the characterization of soil surface features. This will be done through analysis of spectral indices in relation to vegetation and soil parameters.

Countries: field sites in France and Spain; partners in France, Spain and the Netherlands
Website: http://www.geog.uu.nl/fg/demon.html

DEMON-II
Full name: An integrated approach to assess and monitor desertification processes in the Mediterranean basin
Time span: March 1996 – February 1999
Aim: The objective is to use an integration of ecological models and information from operational earth observation and meteorological satellites to assess and monitor regional scale indicators of sensitivity to desertification.
Description: Conceptual and methodological pathways for deriving coherent indicators of vegetation abundance and the erosional state of soils from remotely sensed imagery (reflective and thermal domains) will be optimised, including methodological refinements which permit to use this approach within a larger variety of climatic conditions throughout the Mediterranean. The project further attempts to define the conceptual requirements needed for designing an operational 'Satellite-based Desertification Observatory' for the Mediterranean basin. The development of an approach for future projections of desertification, particularly with respect to the risk of soil erosion and further degradation of vegetation communities (Desertification Susceptibility Index) is an essential part of the project activities.
Countries: field sites in France, Spain and Greece; partners in Germany, The Netherlands, Spain, France and Greece
Website: http://www.geog.uu.nl/fg/demon.html

DESERTLINKS
Full name: Combating desertification in Mediterranean Europe : linking science with stakeholders (see also DIS4ME)
Time span: December 2001 – March 2005
Aim: The projects primary objective is to contribute to the work of the UNCCD by developing a desertification indicator system for Mediterranean Europe.
Description: There will be extensive collaboration with local stake holders in desertification affected regions in order to identify impact indicators relating to perceptions of land function; driving force and pressure indicators relating to decision making; and response indicators relating to land management measures taken to combat desertification. Composite indicators will be developed combining these stakeholder-identified indicators with bio-physical and socio-economic state indicators already developed for Mediterranean Europe. Together they will form an environmentally sensitive area identification system, for use at the sub-national scale. In addition, coarse scale modelling of soil erosion, salinization and channel processes will provide a regional degradation index at the Mediterranean-wide scale. Finally the indicators of different scale and type will be combined into a desertification indicator system for Mediterranean Europe. The system will be used to explore different management options identified by the local stakeholders. There will be close collaboration with both local stakeholders and the National Committees to test the application of the indicator system to new regions and to validate the local identification of high risk areas and the implications of local scenario analyses. Finally the experiences gained in both the testing and validation will be formulated into guidelines for the UNCCD on the development and use of indicators to manage desertification.
Countries: Field sites in Portugal, Italy, Spain and Greece, partners in Portugal, Spain, Italy, Greece, the Netherlands and the UK.
Website: http://www.kcl.ac.uk/projects/desertlinks/
NB: DESERTLINKS forms a cluster with GEORANGE, MEDRAP and MEDACTION, see also these project descriptions and their websites.

Desert*Net
Full name: Desert*Net (German Competence Network for Research to Combat Desertification)
Time span: long term / not specified
Aim: Desert*Net was founded to form a binding link between different scientists who aim to investigate the complex causes and effects of desertification in interdisciplinary research approaches. The network aims at facilitating and structuring the communication on knowledge, and mobilizing the necessary research on dryland degradation issues.
Description: Desert*Net, as a network of scientist and experts, provides rational data outputs, gives advice on scientific methods and projects, and promotes the co-operation between and to institutions in Germany

that work on various fields of desertification research. Desert*Net´s expertise is based on an interdisciplinary group of scientists with long-term field and laboratory experience in basic and applied research on desertification in over 40 countries. Objections include: identifying pressing problems with regard to desertification; developing innovative and interdisciplinary research concepts that are feasible and applicable; raising public awareness of the alarming state of desertification; strengthening and supporting research capacities in order to promote scientific co-operation with affected countries; establishing and intensifying linkages with international research partners; and establishing a mechanism for policy advice. The network is open to all scientists sharing its vision.

Countries: worldwide, board and member-institutes in Germany

Website: http://www.desertnet.de/

DESERTSTOP

Full name: Remote Sensing and Geoinformation processing in the assessment and monitoring of land degradation and desertification in support of the UNCCD. State of the art and operational perspectives

Time span: August 2004 – July 2006

Aim: This specific support activity intends to serve as a platform to bring together leading scientists working in the fields of remote sensing and geoinformation with a focus on desertification and land degradation with potential users.

Description: In the past years, the persisting threat of desertification and degradation of natural resources has resulted in a large number of initiatives and research efforts on a global scale, including the UNCCD. Despite significant progress, knowledge still remains fragmented in many fields, especially with respect to the definition of related indicators or early warning systems. A dedicated conference striving for attention on a world wide level will be the core around which various other activities are assembled. Commissioned studies in specific target fields will provide an overview on the state of the art, being complemented through methodological and application studies.

Countries: apparently worldwide; coordinator in Germany

Website: no website

DESERTWATCH

Full name: DesertWatch

Time span: September 2004 – half 2006

Aim: The project aims at developing a user-tailored, standardised, commonly accepted and operational information system based on EO technology to support national and regional authorities of Annex IV (Northern Mediterranean) countries in reporting commonly to the UNCCD and assessing and monitoring desertification and its trends over time.

Description: This will contribute to:

- The creation of standard and comparable geo-information products from country to country about the status and trends in desertification;
- The creation of a common framework for reporting to the UNCCD for Annex IV countries;
- The creation a common basic infrastructure as a base for further developments where EO plays a key role;
- The development a common methodological approach for all countries in Annex IV to assess and monitoring the desertification problems and identify trends and potential scenarios.

From a methodological viewpoint the project shall exploit the most consolidated scientific results derived from the several research and application projects. In this context, the project aims at bringing the gap between the extensive research work carried out in the last years and the operational needs of the user community.

Countries: Field sites in Italy, Portugal, Greece and Turkey; partners in Italy, Spain, the Netherlands, Germany.

Website: http://dup.esrin.esa.it/desertwatch/

DISMED

Full name: Desertification Information System for the Mediterranean

Time span: 2000 - ?

Aim: To improve the capacity of national administrations of Mediterranean countries to effectively program measures and policies to combat desertification and the effects of drought.

Description: The main problems to be addressed can be summarized as follows:

- National and sub-regional policies to combat soil degradation are often based on an empirical evaluation and qualitative analysis, rather than on information resulting from data analyses, due to the limited interaction between scientific institutions and policy makers.
- The NAPs of the Mediterranean countries are not based on common and homogeneous information, due to the scarce linkages amongst the national institutions of the different countries.
- Consequently, national and sub-regional policies in the Mediterranean Region are not sufficiently appropriate and consistent.

The aim will be pursued by reinforcing the communication amongst national administrations, facilitating the exchange of information and establishing a common information system to monitor the physical and socio-economic conditions of areas at risk, assess the extent, severity and the trend of land degradation.

Countries: Participating countries: Algeria, Egypt, France, Greece, Italy, Libya, Morocco, Portugal, Spain, Tunisia and Turkey.

Website: http://dismed.eionet.europa.eu/

ECO-SLOPES

Full name: Eco-engineering and conservation of slopes for long-term protection from erosion, landslides and storms

Time span: June 2001 – September 2004

Aim: The stabilizing and reinforcing effects of vegetation on natural and artificial slopes will be examined with a view to developing adequate management strategies and new techniques

Description: Recent catastrophic landslide and storm events in Europe, resulting in the loss of human life and irreparable damage to rural communities, illustrate a huge need for improved management of unstable slopes in both urban and natural environments. Current geo-engineering measures, involving the use of reinforcing techniques offer an expensive solution to the problem, and can only be used in high-risk, accessible areas. In this multidisciplinary project, the stabilizing and reinforcing effects of vegetation on natural and artificial slopes will be examined with a view to developing adequate management strategies and new techniques for the prevention of such disasters. The relationship between tree and woody plant architecture, root anchorage and root reinforcement will be investigated and correlated to soil mechanical and physical properties, as well as slope stability.

Countries: Field sites in UK, Italy, France, Greece, Spain; partners in France, UK, the Netherlands, Greece, Italy and Spain

Website: project website (www.ecoslopes.com) not working

GEORANGE

Full name: Geomatics in the assessment and sustainable management of Mediterranean rangelands

Time span: January 2001 – March 2004

Aim: The project aims at formalising concepts and strategies for multi-functional range assessments and the design and implementation of management plans, based on a dedicated software environment that includes range-specific remote sensing and GIS-related processing modules for end-users.

Description: The GeoRange approach is based on an adequate consideration of the multi-functionality of Mediterranean rangelands. Drawing from conceptual research and specific field studies, the project aims at creating an efficient documentation, management and decision support environment. This will be dedicated to the specific needs of rangeland ecologists, managers and conservationists, and strive to meet the requirements defined by administrative authorities. It will be based on a thorough assessment of range conditions, the identification of physical and socio-economic factors driving ecosystem processes, and the design and implementation of multi-functional range management scenarios derived in relation to three case studies on quite different rangeland problems.Additionally, GeoRange aims at providing actual and potential end-users with software modules including remote sensing and GIS-related processing tools for optimising their management actions.

Countries: field sites in Greece, Italy and Spain; partners in Germany, Italy, Spain en Greece.

Website: http://www.georange.org/georange/

NB: GEORANGE forms a cluster with MEDACTION, MEDRAP and DESERTLINKS, see also these project descriptions and their websites.

GLASOD
Full name: The Global Assessment of Human-Induced Soil Degradation
Time span: 1987 - 1990
Aim: To produce a global map of soil degradation and a soil degradation database
Description: The GLASOD project has produced a world map of human-induced soil degradation. Data were complied in cooperation with a large number of soil scientists throughout the world, using uniform Guidelines and international correlation. The status of soil degradation was mapped within loosely defined physiographic units (polygons), based on expert judgement. The type, extent, degree, rate and main causes of degradation have been printed on a global map, at an average scale of 1:10 million, and documented in a downloadable database. Information about the areal extent of human-induced soil degradation can be found in an explanatory note.
Countries: worldwide
Website: no project website; information through
http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/GLASOD.htm

INDEX
Full name: Indicators and thresholds for desertification, soil quality, and remediation
Time span: January 2004 – December 2006
Aim: The mechanisms of land degradation are well known and have been the object of many EU studies. The prime goal of INDEX is to apply this knowledge to develop modern, rapid, sensitive, universal, multivariate indicators with which the dynamic state of land degradation as well as its remediation can be assessed.
Description: Changes will often be slow and subtle. An early warning system is needed to indicate the need for countermeasures, while they are still economical. INDEX will rely on previously supported Commission projects and will disseminate its results to subsequent projects. The indicators of desertification mechanisms will be developed on fields in various stages of degradation and remediation and verified on a pan European basis on sites selected with stakeholders. They will be based on: microbiology including molecular biology and genetic diversity; characteristics of the dynamic humus pool and humo-enzymes; and soil physics including rheology. Results will be extrapolated to thresholds to indicate when remediation is economically unfeasible.
Countries: Field sites in Germany, Hungary, Spain and Italy; partners in Germany, Spain, Austria, Hungary, UK and Italy.
Website: http://www.soil-index.com (English and Spanish)

JEFFARA
Full name: La désertification dans la Jeffara tunisienne : Pratiques et usages des ressources, techniques de lutte et devenirs des populations rurales (Desertification in the Jeffara region, Tunisia : Practice and resource use, combat techniques and development of the rural population)
Time span: 2001 - 2004
Aim: The objectives of the project are: (1) to study, in a desertification context, the problem of access and management of natural resources in a complex basin of segmented agricultural use where water is a preferential vector for the evolution of agriculture, economics and environment; and (2) to propose, after evaluation of the efficiency of the management techniques, not only of their technical performance, but also of their capacity to adapt to the evolution of the users' practices, solutions for the decision to apply management tools and other actions to combat desertification, based on the integration of different strategies and their capacity to regulate.
Description: The Jeffara region, located in south-east Tunisia on the northern fringe of the Sahara, presents climatic characteristics of arid regions (150 – 200 mm rainfall, skeletal soils and important movements of particles). Also, pressure is put on these soils for cultivation (mainly olives) as well as pressure on resources from various sectors, on water particularly (food production, drink water, tourism, irrigation, industry), that can endanger the environment of these resources. From the start, the partners intended to look at desertification not only from the biophysical angle but also in terms of interactions between environment and society and the dynamics of human actions such as adaptation and response of society on ecological and socio-economic changes.

Countries: Field site in Tunisia; partners in Tunisia and France
Website: http://www.up.univ-mrs.fr/wiupenv/labo/d_lpe/equipes/usages/jeffara.html (in French only)

LADAMER
Full name: Land degradation assessment in Mediterranean Europe
Time span: December 2002 – November 2005

Aim: The objective is to provide an assessment of the degradation status of Mediterranean lands on small scales, and the identification of hot spot areas subject to high desertification/degradation risk.

Description: The LADAMER Project proposes an integrated approach to Land Degradation Assessments in Mediterranean Europe. The project aims at supplying products relevant to national and international institutional end-users. The approach is based on an integration of expertise in landscape ecology and soil science, remote sensing, spatial analysis and integrated land use modelling. Different models and techniques that have already proven their validity on local to sub-regional scale will be modified to permit their application on regional scales. The project will use existing data on European land-use, soils and terrain elevation, climatic recordings used for agro-climatic modelling on European scale, remote sensing data archives from the VEGETATION and AVHRR systems, and regionalised socio-economic data.

Countries: Mediterranean member states of the European Communities; partners in Spain, the Netherlands, Germany, Italy and Portugal

Website: http://www.ladamer.org/ladamer/

LUCC

Full name: Land-Use and Land-Cover Change

Time span: October 1996 – October 2005

Aim: The project aims at improving the understanding of the land use and land cover change dynamics and their relationships with the global environmental change.

Description: The primary objectives of the LUCC international project are: (1) to obtain a better understanding of global land-use and land-cover driving forces; (2) to investigate and document temporal and geographical dynamics of land-use and land-cover; (3) to define the links between sustainability and various land uses; and (4) to understand the inter-relationship between LUCC, biogeochemistry and climate. The project has three focus areas: Land-use dynamics – comparative case study analysis; Land-cover dynamics – empirical observations and diagnostic models; and regional and global integrated models. Also, two integrating activities are included in the project: data and classification and scalar dynamics.

Countries: worldwide;

Website: http://www.geo.ucl.ac.be/LUCC/lucc.html

MEDACTION

Full name: Policies for land use to combat desertification

Time span: January 2001 – March 2004

Aim: MEDACTION aims at assessing the main issues underlying the causes and effects of land degradation; and at developing integrated policy options and mitigation strategies to combat desertification in the Northern Mediterranean region.

Description: As in most other semi-arid regions, desertification in the Mediterranean region is largely a society-driven problem which can be effectively managed only through a thorough understanding of the principal ecological, socio-cultural and economic driving forces associated with land use and climate change, and their impacts. For this reason, MEDACTION adopts an integrated, multi-disciplinary approach, involving social and natural scientists as well as the principal stakeholders in the region to: develop land use change scenarios at various scales; analyse effects of past policies in four target areas; analyse the costs of land degradation and benefits of mitigation measures; and develop options for land use policies, mitigation strategies, and incentives to combat desertification. MEDACTION will develop an information and decision-support base on land degradation to assist decision-makers from the local to the European level in the formal and informal decision and policy making process to combat desertification in the Northern Mediterranean Region.

Countries: Target areas in Portugal, Spain, Greece and Italy; partners in Greece, Italy, Portugal, Spain, UK and the Netherlands.

Website: http://www.icis.unimaas.nl/medaction/

NB: MEDACTION forms a cluster with GEORANGE, MEDRAP and DESERTLINKS, see also these project descriptions and their websites.

MEDAFOR

Full name: Consequences for the mitigation of desertification of EU policies affecting forestry activity: a combined socio-economic and physical environmental approach.

Time span: 1998 – 2001

Aim: The overall objective is to develop, apply and test methodologies applicable widely within the EU for investigating the socio-economic and soil sustainability impacts of land use and land management practice change arising from various EU policies and aid schemes which affect forestry activity in selected areas of the Mediterranean vulnerable to land degradation.

Description: The MEDAFOR project focuses on the hydrological and soil degradational consequences of EU polices and funds affecting forest expansion, development, change and management in desertification-prone areas of the northern Mediterranean. It aims to develop methods for achieving sustainability of EU forestry-related activities thereby supporting the idea of a healthier planet through protecting natural resources. It is multidisciplinary and addresses the need to consider socio-economic development in striving for environmental sustainability. It seeks to improve the factual basis for EU environmental policy; to contribute to integrating the environment into EU agricultural and cohesion policies; and to evaluate the benefit of incorporating 'key actors' views in improving EU forestry-related policies. The project has three main foci:

- the development of a transferable methodology for determining soil erosion hazard under different land management types.
- the integration of socio-economic factors in assessing likely forestry-related impacts on soil erosion.
- the incorporation of the opinions of 'key actors' in developing improved solutions to anticipated future degradation.

Countries: Field sites in Portugal, Spain and Italy; partners in Portugal, UK, Spain and Italy.

Website: http://www.geog.plymouth.ac.uk/medafor/medafor.htm

MEDALUS I-III

Full name: Mediterranean Desertification and Land Use

Time span: Overall: 1991 – 1999 (phase I: January 1991 – December 1992; phase II: January 1993 – September 1995; phase III: January 1996 – June 1999)

Aim: The emphasis of the research has changed in each phase and the partners also changed to reflect this. The ultimate goal is the understanding, prediction and mitigation of Desertification in the Mediterranean countries of the European Union.

Description:

- Phase I: The first objective of MEDALUS I was to develop a physically-based model to describe environmental processes operating at the hillslope scale. The model was supplied with data for development and verification from seven field sites located along the northern edge of the Mediterranean. Each of the field sites had the same experimental design and each monitored the same set of 55 parameters. Climate change studies looked at trends in past rainfall and temperature over the entire Mediterranean Basin and general circulation model scenarios were used to generate future climate scenarios also to be used in the hillslope model. Remote sensing was used to develop vegetation and lithological maps over much larger areas. Socio-economic studies set possible future land use changes in the context of past changes from pre-historic to recent times.
- Phase II: Many of the activities started in MEDALUS I were continued into MEDALUS II and other topics were started. The programme of field monitoring was continued and the number and range of special field site studies was expanded. A new, physically-based model (MEDRUSH) was developed, designed to operate at the river basin scale and to simulate landscape changes over hundreds, instead of tens, of years. The climate work continued and expanded into the analysis of extreme events. New investigations were started into ways in which the effects of desertification might be mitigated, using alternative land uses or plant cover strategies. However the major development was the establishment of three target areas, large river basins (in Spain, and two in Italy) in which to develop all the thematic research to a regional scale.
- Phase III: The first objective was to build on the core field and ecological studies, and to consolidate and apply the models in as many areas as possible. The second objective was to develop and apply a methodology for the use of desertification indicators to identify environmentally sensitive areas at the local level. The same methodology was used in all four areas to derive four indicators of soil, climate, vegetation and management quality. The combination of all four indicators gave the environmental sensitivity. In its third objective, MEDALUS III explored opportunities to address the problems of desertification at a Mediterranean-wide large scale. A regional degradation index was developed for the whole Mediterranean region based on potential soil erosion, with inputs of land cover from remote sensing and climate. The fourth objective was to examine some of the important physical processes operating within ephemeral channels and rivers.

Countries: Field sites differed per phase (see description). Phase I had 17 partners, phase II 44 and phase III 30.

Website: http://www.medalus.demon.co.uk/

MEDCHANGE

Full name: Effects of land-use and land management practice changes on land degradation under forest and grazing ecosystems.

Time span: 1997 – 2001

Aim: The two main aims of this project are (1) to investigate what the effect is of changes (increasing forest and grazing activities) on land degradation; and (2) to assess what the current and likely future changes are in land-use and land management practices.

Description: The objectives of the project include:

- To investigate the impacts of land-use and land management practice changes in areas of the Western Mediterranean that are vulnerable to land degradation and desertification on water depletion, soil degradation and vegetation health;
- To assess trends in land-use and land management policies and the perception and response of socio-economic agents, occurring as a result of soil-water conservation policies: a holistic research approach combining both natural environmental and societal and socio-economic dimensions will be adopted in order to improve the basis of policies in support of sustainable development;
- To produce models, both conceptual and semi-quantitative, to describe the relationship between hydrology, vegetation, land use and socio-economic constraints and to build scenarios for alternative land-uses/land management practices, under different socio-economic conditions, in order to obtain a tool for regional planning;
- To establish thresholds through the definition of criteria for evaluation and mitigating land degradation;
- To establish the best practices for land management in order to achieve greater sustainability;
- To reinforce information transfer and result dissemination.

Countries: Field sites and partners in Spain, Portugal, Morocco and Tunisia.

Website: http://www2.dao.ua.pt/RECNATUR/medchange/index.htm

MEDCOASTLAND

Full name: Mediterranean coordination and dissemination of land conservation management to combat land degradation for the sustainable use of natural resources in the Mediterranean coastal zones.

Time span: 2002 - 2006

Aim: The overall objective of MEDCOASTLAND is to contribute to sustainable development, planning and management of natural resources in Mediterranean coastal areas, with particular regard to land and soil degradation and conservation management.

Description: MEDCOASTLAND is a thematic network with the following specific objectives:

- Implementing an effective co-ordination and dissemination of research, studies and projects dealing with land degradation and soil conservation in Mediterranean countries.
- Providing research reviews, dissemination of research results, communication among key players, public access to relevant information, and indications and guidelines to implement good management practices.
- Identifying major gaps in information and knowledge-base to reach a proper regional understanding of sustainable land management.
- Formulating an eco-system based assistance methodology to land users.
- Developing an income-product generating approach in soil conservation management.
- Suggesting more adequate planning policies in coastal areas.

Countries: There are 54 registered users so far.

Website: http://medcoastland.iamb.it/

MEDRAP

Full name: Concerted action to support the northern Mediterranean regional action programme to combat desertification

Time span: January 2001 – March 2004

Aim: The main objective of this Concerted Action is to support the elaboration of the Regional Action Programme (RAP) to combat desertification in the Northern Mediterranean Countries

Description: The project will try to establish a better link between the scientific community and the actors in the relevant areas (Authorities, Decisions makers, NGO's, civil society, represented at different territorial levels) in order to initiate, harmonize and facilitate action and strategies against land degradation/desertification. By means of a wide participatory approach, specific objectives will be to identify (1) the state of the art on desertification topics, to better evaluate the impacts of human activities and planning policies on threatened regions; (2) spatial and temporal priorities and

strategies, to implement prevention/mitigation actions and to improve sustainable land management; and (3) scientific, institutional and political gaps and opportunities, to propose suitable solutions. To achieve these objectives, a wide telematic network for information and knowledge exchange will be set up between scientific community and stakeholders involved in land management at all levels.
Countries: Partners in Spain, Turkey, France, Portugal and Greece.
Website: http://nrd.uniss.it/medrap/medrap_home.htm

MEDRATE
Full name: Mediterranean Rainfed Agriculture Technologies Evaluation
Time span: September 2000 – July 2002
Aim: This project aims to evaluate and assess the impact and adoption of agricultural technologies specially adapted to rainfed agriculture within the framework of well described and defined agricultural systems.
Description: The evaluation and the assessment of impact will be carried at three levels: research, on-farm trials and demonstration; and at-farm level, using quantitative and qualitative data. Data collection will be done by using experimental data and through surveys. Specific scientific and technical objectives are (1) to characterise pilot areas and evaluate main constraints and potentialities of representative rainfed agricultural systems in 7 Mediterranean Countries (Algeria, Egypt, Italy, Morocco, Spain, Tunisia and Turkey) representative of the main rainfed agricultural systems; and (2) to evaluate, at the levels of Research, On-Farm Trials and Farmer, agricultural techniques adapted to rainfed agriculture in the field of Land & Water management, Crop Production, Animal Production, Forestry and Technical and Socio-Economic management.
Countries: Participating countries: Algeria, Egypt, Italy, Morocco, Spain, Syria, Tunisia and Turkey
Website: http://www.iamz.ciheam.org/RAP-RAG/research.htm#Research

MWISED
Full name: Modelling Within Storm Erosion Dynamics
Time span: April 1998 – June 2001
Aim: The objectives of the project are: (1) description of the within-storm dynamics of soil surface roughness, sealing, soil aggregates and infiltration; (2) prediction of rill and ephemeral gully generation and development during erosive storms; (3) production of a generator of synthetic erosive rainstorms able to give useful insight into the relevant within-storm intensity pattern; (4) development of a fully dynamic model taking into account points 1,2 and 3; and (5) development of a pedo-algorithm package for users of item-4 model and other models.
Description: The provision of an effective procedure for simulating the within-storm changes in soil and flow conditions in the landscape will provide a sounder base than presently available for policies designed to target anti-erosion measures. The procedure will also permit different erosion control measures to be evaluated and compared. The association of the simulation procedure with a rainfall generator, able to characterize the relevant 'erosive characteristics' of the rain will enable predictions to be made of likely changes in erosion behaviour in response to changes in climate (rainfall factors) and land use. The overall improved understanding of within-storm changes will contribute to better generic understanding of soil erosion processes and their simulation.
Countries: Data from Italy, Belgium and Spain; partners in Italy, Belgium, UK, Spain, Austria and the Netherlands.
Website: http://www.fi.cnr.it/irpi/mwised/

PESERA
Full name: Pan-European soil erosion risk assessment
Time span: April 2000 – October 2003
Aim: The main goal of PESERA is to develop, calibrate and validate a physically based and spatially distributed model to quantify soil erosion at a regional scale.
Description: A physically based and spatially distributed model will be developed, calibrated and valuated to quantify soil erosion in a nested strategy of focussing on environmentally sensitive areas relevant to European scale. Accurate databases will be compiled and upgraded through satellite image processing and computational techniques. The project will concentrate on promoting a robust and flexible model by demonstrating its performance at different resolutions and across agro-ecological zones, and by ensuring its relevance to policy makers through impact assessment and scenario analysis. A strong expert and end-user network will be established across Europe.
Countries: Europe-wide; partners in Belgium, UK, France, Italy, Greece, Spain and the Netherlands

Website: http://www.kuleuven.ac.be/geography/frg/leg/projects/pesera/index.htm or http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/PESERA.htm

REACTION

Full name: Restoration actions to combat desertification in the northern Mediterranean

Time span: January 2003 – December 2005

Aim: REACTION aims at synthesising the more recent advances in the research on land restoration to mitigate desertification, together with the traditional knowledge on reforestation, and make it available to the National and Regional Action Plans to Combat Desertification in the Annex IV countries of the EU.

Description: The efficiency of restoration initiatives can be improved through the evaluation and transfer of technologies to fight desertification that are environmentally sound, economically viable, and socially acceptable. To approach the evaluation of restoration efforts in the northern Mediterranean from ecological, economic and socio-cultural perspectives, there is a need of incorporating recent advances on indicators and restoration methodologies, and of defining the fundamental information needed. REACTION aims are: (1) to establish a database on land restoration to fight desertification by inventorying well-documented restoration projects in the northern Mediterranean; (2) to exploit the research results produced in projects on restoration, specially those of the EC programmes, for selecting the most appropriate methodology to evaluate the results of restoration projects; (3) to provide restoration guidelines in the light of a critical analysis of old and innovative techniques; and (4) to facilitate access to high quality information to forest managers, policy-makers, and other stakeholders for the promotion of sustainable mitigation actions.

Countries: Partners in Spain, Italy, Greece, Portugal and France

Website: http://www.gva.es/ceam/reaction/Home.htm

REDMED

Full name: Restoration of degraded ecosystems in Mediterranean regions

Time span: February 1998 – May 2001

Aim: Given the need for land restoration, REDMED aims to apply the scientific advances on desertification processes, soil behaviour and plant ecophysiology, on restoring the main identified cases of land desertification spread over the Northern Mediterranean.

Description: REDMED addresses specifically the restoration of extremely degraded wildlands, representative of desertified areas in Mediterranean Europe. The first objective is the development of nursery techniques to optimise seedling and seed adaptation to the extremely limiting conditions in the field. The second objective is the development of restoration field techniques.

Countries: Field sites in Spain, Portugal and Greece; partners in Spain, Portugal, Greece and UK.

Website: http://www.gva.es/ceam/redmed/redmed.htm

SCAPE

Full name: Soil conservation and protection strategies for Europe

Time span: November 2002 – October 2005

Aim: SCAPE aims to develop a platform that recommends (1) which soil functions should be conserved and protected to support sustainable development and (2) how this should be done.

Description: SCAPE is a concerted action funded by the European Commission. It will provide opportunities for discussing the development and application of soil conservation and protection strategies. It will consider data on soils and their use, including the socio-economic driving forces. It will support the organisations responsible in their efforts to obtain the data and information needed for end users and the sustainable protection and conservation of European soils. To achieve its mission SCAPE will set up working groups that will collect and review information and organise four European workshops where soil conservation/protection and other scientists, data users and providers and policy makers can discuss and review soil conservation and protection strategies in contrasted regions of Europe.

Countries: Partners in the Netherlands, Norway, Spain, Israel and France.

Website: http://www.scape.org/

TERON

Full name: Tillage Erosion: Current State, Future Trends and Prevention

Time span: March 1997 – August 2000

Aim: The aim of the project is to provide information and tools to remediate and/or prevent the problem of tillage erosion.

Description: Under conditions of mechanised agriculture, tillage erosion is a very important process contributing enormously to soil degradation. Though the indirect effect of tillage operations on soil erosion by water has long been recognised, the direct effect on downhill movement of soil has largely been neglected. The major objectives of the project are (1) collect the necessary data to assess the extent of tillage erosion and its effect on soil quality in Europe (current status), (2) to predict likely future effects of tillage erosion on soil quality and (3) to develop tools and guidelines for the prevention of tillage erosion.

Countries: Partners in Belgium, UK, Denmark, Greece, Italy, Spain and Portugal

Website: http://www.fi.cnr.it/irpi/teron.htm

VULCAN

Full name: Vulnerability assessment of shrubland ecosystems in Europe under climatic changes

Time span: January 2001 – December 2004

Aim: The overarching goal is to assess the vulnerability of European shrubland ecosystems and the rate and extent of changes in these ecosystems as affected by climate change.

Description: VULCAN investigates the these impacts by experimental manipulations of 6 shrub land ecosystems in Europe and studies of the effects of warming and drought on plant, soil, fauna and soil water processes. Temperature manipulations are done as nighttime warming and drought as 2-month summer drought. Based on the experimental results and existing knowledge on management impacts on shrub land ecosystems an expert system is developed to conduct vulnerability scenarios for shrub lands in order to evaluate and prioritise management actions. The results are further integrated with experiences from potential end users through an end user panel and management guidelines to counteract climate change effects on shrub lands are developed.

Countries: Field sites in Spain, Italy, the Netherlands, Hungary, UK, and Denmark; Partners in the same countries and in Estonia

Website: http://www.vulcanproject.com/