Desertification in the Mediterranean

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Abstract.

The desertification is a dynamic and complex system of land degradation. To understand its behavior it is necessary to identify the physical and anthropogenic process have acted on the land and their interrelations. The problem is one of multiple degradation processes overlapping at different temporal and spatial scales and over different systems.
To understand the origins and evolution of the desertification in the Mediterranean, past and present natural and anthropogenic causes and processes are reviewed.
They have acted on the land and caused extensive but spatially and temporally discontinuous degradation of the natural ecosystems. Soil erosion, flooding, deposition and climatic aridity cycles had taken place before human action started interfering with nature. Physical land degradation has been reversible and natural ecosystems re-established themselves during periods of climatic optima.
Actual causes and processes of desertification are described. Technological advancement, industrialization of agriculture and subsidy policies have accelerated the rate of land degradation during the last 50 years in the areas vulnerable to desertification.
Man’s actions can have positive effects on land if proper practices and policies are identified and applied.

Key words: Desertification, land degradation.

Introduction: Occurrence of desertification

The desertification has become a major environmental issue in scientific, political and even general public circles and the term captures a sense of moving deserts, drying lakes and starving people (Thornes, 1996). The international community has long recognized that desertification is the most important economic, social and environmental problem of concerning to many countries in all regions of the planet. The World Atlas of Desertification (UNEP 1997) which summarizes the current state of scientific knowledge on the dry lands of the globe, assesses that more than 6.1 billion ha, 47.2 % of the Earth's land surface, is dry land (Fig. 1). Nearly 1 billion ha of this area are natural1y hyper arid deserts, with very low biological productivity. The remaining 5.1 bil1ion ha are made up of arid, semiarid and dry sub humid areas, part of which have been degraded since the dawn of civilization while other parts of these areas are still being degraded today. These lands are the habitat and source of livelihood for about a fifth of the world's population. They are areas experiencing pressures on the environment caused by human mismanagement, problems that are accentuated by the persistent menace of recurrent drought.

Desertification adversely affects nearly 3,100 million ha of rangelands (80 % of their total area in drylands), 335 million ha of rainfed croplands (60 % of their total area in drylands), and 40 million ha of irrigated croplands (30 % of their total area in drylands), in all, up to 3,475 million or 70 % of total area of drylands (Dregne, 1986, 1991).

(From Dregne, 1986, 1991)

Figure 1: A) The extent of arid , semiarid and subhumid lands in the world. B) Status of desertification

Also Mediterranean Europe has been recognized affected by the desertification and by its environmental and social impacts.

In Europe, desertification is widespread in the mediterranean semi-arid and dry subhumid regions (Perez-Trejo, 1994; Brandt & Thornes, 1996; Mairota *et al.,* 1998). This includes the southern and eastern parts of the Iberian Peninsula, parts of Mediterranean France, most of the Mezzogiorno in Italy, Sardinia and Corsica and most of Greece, including the islands, especially Lesvos. Generally the most critical areas were identified as having less than 600 mm of rainfall per year, distributed over a few months, with a long dry hot summer. Most of the Mediterranean countries has been identified as having "very high", "high" or "medium" levels of soil degradation severity.

The United Nation Convention to Combat Desertification (http://www.unccd.int) identified Portugal, Spain, Italy, Greece and Turkey as countries with a marked problem of desertification because of the occurrence of particular conditions over large areas:

i. Semi-arid climatic conditions affecting large areas, seasonal droughts, very high rainfall variability and high-intensity rainfall.

ii. Poor and highly erodible soils, prone to develop surface crusts.

iii. Uneven relief with steep slopes and very diversified landscapes..

iv. Extensive forest coverage losses due to frequent wildfires,

v. Crisis conditions in traditional agriculture with associated land abandonment by rural populations and deterioration of soil and water conservation structures,

vi. Unsustainable exploitation of water resources leading to serious environmental demage including chemical pollution, salinization and exhaustion of aquifers.

vii. Concentration of econonomic activity in coastal areas as result of urban growth, industrial activities, tourism ad itrrigated agriculture.

Desertification according to the definition of the United Nations Convention is confined to areas affected by aridity. This definition is somewhat biased since the phenomenon may also take place under humid climates (as in Scotland and Iceland). Thus, desertification can be considered an extreme case of land degradation.

Land degradation has no spatial and temporal confinement. It has taken place at various times and under a variety of physical conditions, with and without the intervention of man. Catastrophic degradation of land resources has taken place in all climatic regions of the Earth.

History and development of desertification in the Mediterranean

The causes of desertification fall within two major groups: natural and anthropogenic. The history of desertification in the Mediterranean actually follows the course of evolution of these two groups of causes and of their interactions.

In the course of times, in some occasions, land resources followed a declining path; in other occasions land resilience, positive feed back and self-reinforcing mechanisms interrupted the declining course and repaired the damages when critical thresholds have not been crossed. Intensive soil erosion episodes during the Quaternary denuded higher slopes but at the same time created colluvial and large alluvial deposits, which had much greater biomass productivity than the original sloping lands. These lands have supported the proliferation of the human communities.

While desertification in the Mediterranean does not occur without irrational human activity, there are many cases where man’s interference with nature has produced new socio-ecological systems that contribute to his welfare more than the natural ones. Such a case is the sustainable agriculture, which may have, through the ages, decreased biodiversity but it has provided livelihood for a greater number of inhabitants than the natural system.

Evolution of the physical environment

Climatic fluctuations have always been changing the landscapes and the vegetation on Earth and geological evidence shows that these fluctuations occurred in periodic cold-warm an dry-wet cycles. As a result we see in a given point at a given moment a mixture of landscapes, the succeeding inheriting the preceded one, which are difficult to unriddle.
The evolution of the physical environment in the Mediterranean has been examined by many authors such as Gilman and Thornes, 1985;Verheye 1991; Tzedakis, 1993; Runnels, 1995; Grove, 1996; several researchers of the

ARCHAEOMEDES Project, 1998, (summaries by van der Leeuw; McGlade and van der Leeuw). The main physical events that occurred during the later period of Earth's life in the European Mediterranean Region can be summarized as in Table 1.
The descriptions indicate that natural events that could trigger physical processes such as soil erosion, sediment transport, gullying, cooling, aridification and biological changes, capable of extensive land degradation, have occurred even in the absence of human interference.

Almost all of the Mediterranean region, during the cold stages of the Quaternary, was covered by an open low biomass producing steppe-type vegetation. This type of vegetation cover accounted for about 70% of the land for 2 million years and 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. The advance of forests, which occurred during the temperate interglacial times, interrupted the periods of land instability.

It seems that soil erosion had been more intensive on the colluvial and alluvial deposits than on the higher slopes because the former were in the path of the waterways (Bailey et al., summary by van der Leeuw, 1998).
Decrease in rainfall intensity warmer temperatures and sea level rise contributed to higher rates of soil development.

During the last 5,000 years, the Mediterranean climate became drier and an increase in the amplitude of its fluctuations increased the risks of soil erosion. Thus, weakly developed soils with high sensitivity to erosion predominated during this period. Human intervention, during this period became a significant factor, which contributed to the instability of the land systems.

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5 million years BP. Salinity Crisis, sea level drop, closure of Gibraltar straits, Evaporation fault displacement, tectonic uplifting, exposure of Soft rocks, catastrophic erosion.

300,000-25,000 BP Sedimentation of basins during cold periods, formation of fluvial terraces in Greece. Southern Europe covered by Artemisia steppes with scattered forest stands.

15,000 BP Glaciers retreated. Pine-Juniperus forest appeared followed by Oak forest.

11,000 BP Strong cooling, lower precipitation. Deposition of wind blown silt from Africa. Juniperus-Pinus-Amygdalus-Pistacea forest and steppe predominate.

10,000-0,00 BP Increase of temperatures and precipitation, arid conditions declined. Deciduous forests expanded, Appearance of wild olive tree.

10,000 and 8,000 BP Torrential rainfalls

Around 8,500 BP Major dry crises

8,400-7,500 BP Climatic optimum

7,400- 0,00 BP High-level glaciers expanded in southern Europe. Climatic fluctuations until a few centuries ago (Little Ice Age) caused vertical shifts of snow and tree lines had no significant effects on the Mediterranean ecosystems. Major drought crises around 3, 500. Wild fires occurred also prior to agriculture

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Table 1: Chronological sequence of natural events.

Human intervention

Man has been on the Earth for about 1.6 million years. However, his actions started having marked effects on the European natural ecosystems since the Neolithic Age and became quite prominent during the Bronze Age. The human interference has not been linear. It shows maxima and minima that coincided with periods of population increase and decline respectively.

The history of man's intervention on the land of the Mediterranean Europe suggests that human pressures have followed a non-linear increasing trend since the Neolithic Age with several interruptions. Periods of low human activities allowed the recovery of some natural ecosystems. These interruptions show spatial and temporal variability throughout the region. Human pressures have been enormously intensified during the last 50 years so that there are no remaining pure natural ecosystems in the Mediterranean Europe today.

The study of the human activity on the Earth has provided substantial evidence of its periodic fluctuations. Population increases and decreases may be attributed both to physical changes of the environment and to man's own activities. An exponential increase in population has been taking place during the last centuries. At the same time the effects of the natural episodes on the human communities diminishes as technology advances. Whether we are at metastable equilibrium or not and what will be its duration will be seen in the future.

There is no evidence in the Mediterranean Europe of physical degradation leading to desertification without human action. According to findings of the ARCHAEOMEDES project, land degradation is immediate when physical degradation is in phase with agro-pastural activities.

On the other hand long time human impact fragilizes the ecosystem, so that minor oscillations in the physical parameters might bring about severe land degradation. Under these assumptions periods of possible desertification and resilience may be traced along with the history of physical and human evolution.

The contemporary reality

The causes of degradation are variable and quite complex. A severe and permanent decline of land's productivity, that will result in the desertification and desertion of an area, requires a certain conjunction of natural and social circumstances (van de Leeuw, 1998). It occurs as soon as one or more variables accelerate or slow down out of proportion, not allowing the other ones to keep up with them, thus leading to different dynamic equilibria of the system. One may add that at the new equilibria, the life and diversity support capacity of the system may be diminished. The physical and socio-economic factors, which are responsible for this loss are described below.

Climate and its variability

The contemporary climate of the area follows a warming and drying path. Statistics indicate that a general warming trend started around 100 years ago and it has not been reversed (Berger, 1986). The period of 1931-60 had been one of the warmest in Europe during the last 500 years. There are also long periods of drought. Yearly rainfall is irregularly distributed, particularly in the drier zones. The variation increases with decreasing mean annual rainfall.
From the climatic standpoint, the phenomena that most characterise the desertification process are aridity, drought, and the erosive action of rain.

Aridity is a climatic characteristic determined by the simultaneous scarcity of rain and high evaporation that subtracts moisture from soil. The method most used to detect arid zones is based on the assessment of the ratio of the climatic variables, creating a moisture deficit index called aridity index. To calculate the value of this index, it is necessary to compare the incoming moisture flow (rainfall) with the potential outgoing moisture flow (potential evaporation). While rainfall is a commonly recorded climatic variable, evaporation can be estimated only by resorting to empirical formulas proposed by various authors. On the basis of the ratio of monthly precipitation (P) to monthly potential evapotranspiration (PET), it is possible to assess the aridity index (P/PET). Index values lower than 1 indicate an annual moisture deficit and lower than 0.65 conditions of aridity.

Drought is a normal climatic feature of the Mediterranean countries that also strikes non-arid areas when precipitation is sensibly lower than normally recorded levels. Drought has no predictable patterns of occurrence and has serious ecological, economical and sociological effects. Drought may influence the degree of territorial degradation mainly by causing damage to agricultural and livestock production activities. In fact, natural ecosystems generally have the necessary resilience for withstanding periods of drought, while the productive sectors that depend on a constant water supply may be damaged. Drought in arid zones may break the fragile balance that exists between environmental resources and production activities, causing food crises, the abandonment of entire territories, and even migration and conflicts. For the identification of drought events, various indicators permitting the calculation of the length and intensity of the drought are used.

Rain's erosivity is due to the intensity of the precipitation. When short but intense rain falls on soils unprotected by vegetation coverage, the impact of raindrops and the subsequent sheet and rill erosion removes the soil's surface layer that is rich in organic material. Arid, semi-arid, and sub-humid areas are exposed to the risk of short but intense rains that, instead of mitigating the effects of the scarcity of rainfall, cause erosive phenomena, thus opening the way for desertification.

The future evolution of the climate, following the constant increase in the atmospheric concentration of greenhouse gases such as carbon dioxide, methane, nitrogen protoxide and others, discussed in the Framework Convention on Climatic Changes, will likely lead to a global temperature increase.
The scenarios regarding the future climatic changes, elaborated using general atmospheric circulation models, agree in indicating an increase in global temperature over the Mediterranean basin area, but do not yet provide a consistent picture of the precipitation and ground moisture trends. The most recent climatic simulations, with reference to the temporal horizon of 2025-2050, produced Mediterranean scenarios with temperature increases in the winter between 1.5° and 3.5° C, and in the summer from 0.6° to 1° C. There is not yet agreement as to the sign and the extent of the precipitation variations at the Mediterranean basin level because of the intrinsic difficulty in simulating the hydrological cycle on climatic time scales.

Geo morphological factors

Steep slopes characterize the present landscape of the Mediterranean Europe; man altered vegetation, and over-exploited soil and water resources.
The above described physical conditions make a large part of the Mediterranean lands vulnerable to desertification. The primary processes are soil erosion by water, drought, and secondary salinization .
Factors responsible for the high rates of soil erosion are those, which apply all over the World. Some of them are particularly adverse in the Mediterranean:

- The steep slopes
- The insufficient protection of the land by a disturbed perennial plant cover and vegetation structure, and its low resilience in the desertification sensitive areas.
- The low erosion tolerance of the prevalent litotypes (limestone, marls..)
- The high erodibility of the soils (particularly on Pliocene formations).
- The high erosivity of rainfall due to its irregular temporal, spatial and intensity distribution.
- The long history of intensive human interference.

Country	High risk area	Moderate risk area	Low risk area	Excluded area	Total area
	Km2%	km2%	Km2%	Km2%	Km2
France (S)	16,3559	37,90020	93,44349	42,46322	190,161
Italia	82,36827	85,21128	122,41641	11,3034	301,278
Hellas	57,41443	27,43621	27,02721	20,11315	131,990
España	202,10141	205,15741	69,66214	20,5984	497,518
Portugal	61,12068	21,89025	4,9186	1,0001	88,928
EU (South)	419,33835	37759431	317,46626	95, 4778	1,206,875

(source CORINE, 1992)

Table 3: Potential erosion risk in the southern EU countries.

Table 3 shows that large sections in each of the EU Mediterranean countries are at high and moderate soil erosion risk. The total area at risk amounts to 66% of the total area that these countries occupy. Thus, if man does not restrain himself from irrationally interfering with the physical environment, land degradation and desertification, through soil erosion, will be extensive.

The prevalent litotypes in the Mediterranean are limestones and marls. Irreversible desertification of limestone slopes is quite extensive, particularly in the eastern regions. Land on limestone is very vulnerable for the following reasons:

a. The high permeability of the bedrock induces a more arid microclimate than other rock formations.

b. Soils developed on this parent material are thin because the residue that remains upon its weathering is very small, usually less than 2%. Actually some of the soil material consist of wind blown silt from Africa. Such an extensive deposition occurred around 10,000 years before present and continues until today.

These two conditions are responsible for the low erosion tolerance of the soils and the low rate of recovery of damaged vegetation. Thus land degradation and desertification proceed faster on the sloping limestone lands than on other landforms.

Deforestation of coastal areas has been going for 4,000 years and has resulted in accelerated erosion on the limestone slopes, critical reduction of soil volume and in desertification. This is documented in Attica, Greece by Plato’s writings in Critias; "Soil has been carried to the bottom of the sea.. Earthy high mountains, that in the past carried tall forest and large pastures, have become rocky lands and look like the bones of a sick body... In the past rain water was utilized and did not run on the barren land to the sea as it does now. It infiltrated and was stored into the soil and it was distributed in springs, fountains and river streams".

These processes continued to expand in the mainland until now desertifying a large portion of the limestone formations, especially on southern slopes of the semi-arid and dry-subhumid zones.

Marly formations when undisturbed form deep fertile soils (Mollisols), characterized by a thick, dark, well structured and rich in organic matter surface horizon. Their productivity was early recognized and were intensively cultivated mostly with cereals until the Archaic times and then with vine, olive trees and orchards. In spite of their productivity, marly lands are sensitive to desertification because:

a. They are hilly and therefore subject to water erosion

b. The texture of the parent material is silty and mostly structureless. Once the rich in organic material and well structure top soil is removed, the exposed underlying horizons acquire high rates of erosion because of their high erodibility.

a. The surface crust that usually forms on the subsurface horizons reduces water infiltration, increases runoff and inhibits the emergence and the rooting of the young plants. The recovery of protective vegetation is very slow and erosion is further accelerated.

b. Biomass production on these soils is very sensitive to soil moisture. It is high when the available soil moisture is sufficient, but drops quickly when it diminishes. Thus, under conditions of drought, these soils are more sensitive than even shallower soils on other parent materials.

The above conditions prevail in the semi-arid and arid zones, where desertification is extensive on the marly landforms. It is particularly extensive in Southeastern Spain.

Deforestation

The transformation of forest systems into agricultural ecosystems, often for animal husbandry purposes, and the excessive exploitation of forest resources and their destruction is causing an ever-growing area of land to be exposed to the risk of degradation.

The consequences of deforestation are less severe in humid areas where forests, when there are no fires, re-grow in a relatively short time. Debrushing, often referred to as "cleanup", is still often carried out and considered useful for reducing the risk of fires and fostering the natural regeneration of the woods. In reality, this practice, which exposes the ground, accentuating erosion, altering the microclimate and damaging the fauna, is very harmful. It should also be kept in mind that where there is pasturing, the only chance for tree species to re-grow from seed lies in the possibility for the seedlings to grow sheltered by bushes, especially if the latter are thorny, thus managing to reach such a size that they are resistant to the gnawing of animals.

Forests and shrublands, in arid and sem-arid areas, have been declining in recent years in favor of cultivated lands and pastures. The area covered by forests and brushes in the Guandalentin basin in Spain has declined by 50 % since 1947 (Lopez-Bermudes et al. 1998). In other cases forest show a comeback trend to the abandoned and deserted lands.

Wild fires have been causing an extensive damage to forested areas. They are detrimental in the sensitive climatic zones, especially when they are followed by grazing or if they re-occur before the trees reach the fruiting stage. Pine forest has been subjected to frequent and extensive fires, which show an upward trend during recent years. In Greece the burned areas show a general increasing trend in the last 20 years. A significant number of them (25%) have been intentional criminal acts, whereas negligence accounts for another 28%. The area of forest land that has been burnt in the last 25 years amounts to approximately 1, 500, 000 ha, which is almost 50% of the total forested area of the country.. Table 4, that shows the average annual number of forest fires occurred during the decade 1981-1990, confirms the gravity of the problem.

Portugal	Spain	France	Italy	Greece
8,397	10,210	4,475	10,999	1,275

(Source: Eurostat, 1995)

Table 4: Average annual number of wild fires in the EU Mediterranan countries during the decade 1981-1990.

Forests have been expanding in parts of the countries of European Mediterranean, during the last decades. During the period 1965-1984, the total forested area of the region has grown by 6,462,000, which represents a 14% increase (Le Houérou, 1990). The advancing forests have occupied abandoned marginal agricultural lands and pastures. However, most of the naturally afforested areas are located in climatically favorable and moderately damaged lands. Natural afforestation of abandoned lands in the desertification threatened areas is not always possible because of climatic limitations and advanced degrees of soil degradation.

Water resources

Up to a few decades ago, in many areas of the globe the water resource was considered widely available and at very low costs. Only now the changes in climate, widespread pollution, and irrational use of underground resources have raised the water problem, also in relation to the increasingly burdensome cost for its supply.

The water problem is most felt in arid geographical areas, which unfortunately are becoming more extensive because of global climatic changes and the excessive exploitation of the soils.

In order to sustain the growth of the world population, which has already gone past the 6 billion mark, humanity must reckon with industrial development, coupled with a sharp increase in consumption and new social and economic needs.

The WHO (World Health Organisation) has estimated that the consumption of 1000 liters of water per person per year is the limit below which it is impossible to have economic development and guarantee people’s health and wellbeing.

In developed countries the daily per capita consumption for food uses is 3-4 litres, but hundreds of litres are also consumed for personal uses. This consumption must be combined with that necessary for food production and all industrial activities. To produce one kilogram of wheat, between 1,000 and 2,000 litres of water are used, while for one kilogram of meat, around 5,000 litres are necessary. The production of one kilogram of steel requires a consumption of 150 litres, a kilo of paper up to 300 litres, and a pair of leather shoes around 80 litres.

Water resources considered at the country level, are at present sufficient in all the countries of the Mediterranean Europe, but there are asymmetries in their seasonal and spatial distribution in all of them. Serious supply-demand imbalances are the result of climatic irregularities, irrigated agriculture, urban sprawl in coastal areas and increase in tourism.

In the semi-arid regions, the water cycle is discontinuous. As a result water channels and rivers may be dry for much of the year. There is a deficit between the locally available water and the consumption needs in the desertification sensitive areas. This deficit is growing as consumption increases, while available resources do not increase. It reached dramatic dimensions in the Guadalentin basin and in Murcia during this decade (Lopez-Bermudes, 1998).

The negative gap between precipitation and potential evapotranspiration is very large. Consequently, the principal user of water is irrigated agriculture. The amounts of irrigation water that are consumed annually are given in Table 5.

Country	Millions of hectares irrigated	% of total national farmland	Billions of m3/yr consumed
Spain	3.3	12	20.0
France	1.2	4.0	3.6
Italy	3.6	21.0	13
Greece	1.2	34.3	3.5

(source: Collin, 1995)

Table 5: Average consumption of irrigation water in four Mediterranean countries.

Over- pumping of water may have broad adverse influences on the land, because not only exhausts the underground aquifers but it also reduces channel flow and causes sea water intrusion in the former. In La Mancha, Spain , the extracted water is twice as much as the recharge. According to Chabart et al (1996), Spain will have consumed more than half of its water resources in 30 years. The accelerating effect of water over-pumping on the rate of desertification has been recognized and restrictions are being imposed by the states.

There is a tendency for increased consumption also for the non-agricultural uses of water, such as urban, and industrial. The sharp increase in the influx of tourists, in the desertification sensitive coastal areas, poses a new serious threat to the water resources. It is expected that several hundred millions of tourist will arrive in the Mediterranean basin by the first quarter of the next century.

Degradation processes

Degradation processes can be divided into processes that determine the loss of soil fertility and processes that determine the loss of the soil resource, in terms of a reduction of volume and area. The first category includes a series of processes which can, in turn, be grouped together into chemical degradation processes and physical degradation processes. Among the chemical processes, there are those directly connected with desertification, such as salinisation and the loss of organic substance, as distinguished from those that are not, such as contamination from heavy metals, acidification and the spreading of organic wastes which, in the long run, cause in any case an impoverishment of the resource. This is true especially in certain contexts, which trigger, in turn, desertification processes.

Salinisation

Salinization and sodification of soils have been ongoing old natural processes that turn productive lands into deserts. It takes place in land depressions and coastal plains, where salts are transported by surface runoff and/or capillary rise of ground water. Land in the arid and semiarid zones with inadequate drainage are those that are mostly affected by this phenomenon. There are two paths followed by the processes of soil salinization:

- Addition of soluble salts to the soil by converging surface waters, by rising ground water and by irrigation waters.

- Distilative removal of soil water by evaporation.

A desertification threat that dates back to 5,000 years BP in Mesopotamia and continues through contemporary time, is secondary salinization, which is caused by the irrational application of irrigation, such as the use of water with elevated soluble salt content and / or the failure to meet the leaching requirements.

Modern technology leads to low rates of irrigation water application that does not meet the requirements of leaching the accumulated salts. Tricle irrigation poses greater salinization threat than surface irrigation (Yaron, et al.1973).

Abstraction of ground water from coastal aquifers frequently results in the intrusion of seawater into them. The use of such waters has quickly damaged the soils and reduced their productivity on many occasions. Aru et al. (1996) has classified the coastal soils in Sardinia according to their salinization risk due to this phenomenon.

Desertification due to soil salinization is not as extensive as that which is caused by erosion. The economical loss that it inflicts per degraded unit area is much greater, because it affects high valued productive land, whereas erosion affects mostly marginal lands. The continuing expansion of irrigated agriculture in the Mediterranean is bound to increase the salinization risk and deserves special attention.

Loss of organic substance

The loss of organic substance is considered by many as one of the most important indicators of desertification, in light of the primary role it plays in the processes that determine the fertility of land. Agricultural practices such as the elimination of vegetation residues from the soil surface, excessive mechanical crumbling, with the consequent spreading of the organic substance over a larger volume of land, excessive aeration of the surface layers of the soil, with the consequent oxidation of the organic substance and, lastly, the single-crop system reduced the soil content of organic matter.

Contamination

This aspect particularly concerns industrial areas, mining areas (particularly if abandoned), and major communication routes. Recent studies in abandoned mine areas in Sardinia have brought to light the serious problem of pollution from heavy metals such as lead, zinc, chromium, cadmium, etc. This contamination, found in the south-western part of Sardinia, where the largest mining basin of Italy and the Mediterranean is located, involves vast areas containing streams, aquifers, lakes, lagoons, soils and sea, reached by means of the action of wind and rain.

The socio-economic context.

The world is experiencing a dramatic increase of human interference with nature. This is mainly due to the rapid technological advancement, which enables man to inflict major changes on the natural systems in a short time. Desire for quick economical growth, policy regulations, trade expansion, population explosion in some places, large scale migration, tourism, urban expansion and land use competition are some of the driving forces, which are changing nature in increasing rates by the over-exploitation of its resources. Vegetation, soil and climate are the main components of the environment that are being affected. We are now living in era, during which man has for the first time succeeded in modifying the climate. The principal processes that are followed and the conditions that are conducive to the artificialization of the environment are:

- The low level of the perception by decision makers and the public about the processes and the impacts of desertification.
- The industrialization and mechanization of agriculture, which actually consumes more energy than it produces. This fact by itself, poses a question about the long-term sustainability of this human activity.
- The reduction in the quantity and diversity of natural vegetation by overexploitation and clear-cutting of forest lands, overgrazing the pastures, burning forests and shrublands.
- The overexploitation of the water resources and especially the groundwater of which the level has dropped significantly in the desertification sensitive areas.
- The soil sealing by urban expansion in to productive lands, which has acquired high rates in the recent years.
- The abandonment of marginal agricultural lands that had been brought by man to an unstable equilibrium. These are lands on sloping terrain, which were protected by erosion control structures and practices. Protection ceases and erosion accelerates when they are abandoned.
- The over-pumping of coastal ground water and improper irrigation practices that cause intrusion of seawater into the aquifers and secondary salinization of the soils.
- The tourist influx in sensitive areas has become a problem since it promotes urban expansion to the expense of natural landscapes and contributes to the overexploitation of the water resources
- The emission of green house gases that generally increase temperatures and decrease rainfall in the sensitive areas of the Mediterranean.
- Remedial actions taken by governmental an non-governmental organizations

The mechanization of agriculture has enabled the farmer to bring into cultivation sensitive sloping lands and enjoy a temporary profit from them. Technological advancement and subsidies are concealing the damage done to the land by organic matter loss and soil erosion, until a threshold is reached, after which desertification will becomes inevitable. The areas most vulnerable to degradation are the tertiary marly hills of the semiarid and dry sub humid zones.

Abandonment

Abandonment of marginal agricultural lands started during the decade of 1950 due to the industrialization of the countries involved, the increase in the cost of cultivation, the decrease of profits and the changes in the trade regulations among the countries. There have also been social incentives, which encouraged the farmers to move to urban centers, which are more attractive to them. By 1990 between 10 and 20 percent of agricultural land in the Mediterranean countries was abandoned (Grove and Rackham, 1996.

Land abandonment has been considered as important cause of desertification, but in reality this is not always true, because in many cases recovery of the natural systems follows it. Whether an abandoned agricultural land will move towards recovery or desertification depends on the state of the land at the time of its abandonment and on what follows afterwards.

The most vulnerable lands to further degradation are those on sloping terrain and shallow soils, which have been stabilized by erosion control terraces. These lands are at metastable equilibrium, which exists only as long as the terraces are attended and damages are repaired. Upon abandonment, terraces brake and accelerated erosion begins to remove the soil from them.

Desertification may proceed on sloping land when intensive grazing follows agriculture. The grazing animals consume the vegetation that tries to establish itself on the abandoned fields, the soil is left unprotected and erosion degrades it rather quickly. The system moves toward desertification if the soil productivity and erosion tolerance is low, and the bioclimatic conditions do not allow a speedy recovery of vegetation.

The degradation of abandoned agricultural land is most extensive and frequently leads to desertification on limestone slopes within the semi-arid zone and especially on southern and southwestern aspects.

In cases where the landscape and climatic conditions are not severe, the system moves toward the recovery of the natural environment.

Conclusions

Desertification assessments around the Mediterranean show the importance of the problem and the necessity of mitigating the environmental, economic and social problems. The threat of Climate Change and the indication of deeper and more sustained future droughts may make heavier the problem (Duplessy *et.al.,* 1991; Fantechi *et.al.,* 1991; Imeson *et.al.,* 1992). Combating desertification is essential to ensuring the long-term productivity of inhabited drylands, but to do this it is necessary to know and to measure processes, and to carry out national, and regional action programmes. Combating desertification, is just a part of a much broader objective: the sustainable development of countries affected by drought and desertification.

Remedial and preventive actions to combat desertification have been undertaken by all the Mediterranean countries. Some of actions had been taken before desertification was recognized as a threat to societies. They were technical and legislative measures that targeted toward the control of soil erosion, salinization, water supply, forest protection and reforestation. At the present, both governmental and non-governmental agencies are involved in the battle against desertification. Efforts are made both at the national and international levels. Actions taken could be classified into the following categories:

- Development of strategies through the formulation of the National Action Plans for Combating Desertification and the establishment of coordinating National Committees.
- Policy regulations towards the sustainability of the land resources.
- Legislative measures securing better protection of the environment in general.
- Public awareness activities aiming at improving the level of perception on the existing threat and at securing public consent and support for the action.
- Adoption of incentives for public participation.
- Technical actions such as soil and water conservation practices and works, forest protection and expansion, soil reclamation and irrigation, protection of natural ecosystems and drought mitigation.
- Research and development.

It is worth mentioning the scientific research conducted by several multinational projects, supported by the European Commission. The results of these projects, that studied in depth the factors and the mechanisms of desertification, are available in numerous publications.

References

Aru, A. (1996). Salt water intrusion, waste disposal. Field site Santa Lucia, Sardinia. MEDALUS II. Managing desertification, Final report. Medalus Office, 20a High str., Thatcham, Berkshire UK, 1-38

Audouze,F., Argant, J. Ballais, J.-L., Beeching A, Bel, V., Berger, J.F., Bois, M., Brochi, J.L., Chouquer, G., Favory, F., Fiches J.L. Gazenbeek, M. Girardot, J.J., Jung, C., Mgnin, F., Meffre, J.Cl., Odiot, T., Raynaud, C.

Thiebault, S., Tourneux, F.P., Tschanz, X., Verhagen, Ph. and Zannier, M.P. (1998). Land use, settlement pattern and degradation in the Ancient Rhone Valley (Summary by van der Leeuw). In: S.E. van der Leeuw (ed.) Archaeomedes.Understanding the natural and anthropogenic causes of degradation and desertification in the Mediterranean Basin. European Communities, EUR 18181 EN, Luxembourg.

Bailey, G.N., Ioakim, Chr., King, G.P.C., Turner, C., Sanchez-Goni, F., Sturdy, D., and Winder, N.P. (1998). Norwest Epirus in the Palaeolithic. (Summary by van der Leeuw) In: S.E. van der Leeuw (ed.) Understanding the natural and anthropogenic causes of degradation and desertification in the Mediterranean Basin. European Communities, EUR 18181 EN, Luxembourg.

Ballif,I., Bell, J.,Castro, P.V., Colomer, E., Courty, M. a., Deve, L., Escoriza, t., Fedoroff, N., Fernandez-Miranda, M. Fernandes Posse, D. Carcia, A, Gili, S., Girard, M.C.. Gonzalez Marcelen, P. Jones,M.K., King,G.P.C., Lopez Castro,J.L., Lull, V., Marlin, C., Martin, C. McGlade, J. Menasanch, M., Mico, R. Monton, S., Olmo, L., Rihuete, C., Risch, R., Ruize, M., Sanahuja Yll, E. and Tenas, M. (1998). The environmental dynamics in the Vera Basin (Summary by van der Leeuw). In: J. McGlade and S.E. van der Leeuw (eds.) The Archaeomedes project. Understanding the natural and anthropogenic causes of degradation and desertification in the Mediterranean Basin. European Communities, EUR 18181 EN, Luxembourg.

Berger, A. (1986). Desertification in a changing climate, with a particular attention to the Mediterranean countries. In R. Fantechi and N.S. Margaris [Eds] Desertification in Europe, Com. Eur. Comm. D. Reidel Pub. Comp., Dordrecht, 15-34.

Chabart, M., Collin, J.J. and Marshal, J.P. (1996). Modelling short-term water resources trends in the context of a possible desertification of Southern Europe. In C.J. Brandt and J.B. Thornes [Eds]. Mediterranean desertification and land use. John Willey and Sons Ltd., 398-429

Coccosis, H.N., (1991). Historical land use changes: Mediterranean Regions of Europe. In: F.B. Brouwer, A.J. Thomas and M.J. Chadwick (eds), Land use changes in Europe. Processes of change, environmental transformations and future patterns. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Collin, J.J. (1995). Some aspects of desertification seen from the ground water viewpoint. In R. Fantechi, D. peter, P. Balabanis and J.L. Rubio [Eds] Desertification in a European context:Physical and socio-economic aspects. European Commission EUR 15415, 111-121.

CORINE (1992). Soil erosion and important land resources in the southern regions of the European Community, European Commission, EUR 13233 EN, 96p.

Dregne, H. (1991). A new assessment of the Wold status of desertification. UNEP, Desertification Control Buletin, 6-18.

Enne, G., Mancini, F., Bullittta, P and co-wrkers. (1996). MEDALUS II, Research and policy interfacing in selected regions. Final report. Medalus Office, Berkshire, UK, 599-642.

EUROSTAT, (1995). Europes Environment. Statistical Compendium for the Dobris Assessment. European Environment Agency, Copenhagen.

Gilman, A and Thornes, J.B. (1985). Land use and prehistory in southeastern Spain. Allen & Unwin, London.

Grove, A.T. (1996). The historical context: Before 1850. In: C. Jane Brandt and J.B. Thornes (eds) Mediterranean desertification and land use. John Wiley & Sons, Chichester, UK.,13-28.

Grove, A.T., and Rackham, O. (1996). Physical, biological and human aspects of environmental change. MEDALUS II. Final report. Medalus Office, Berkshire, UK, 39-64.

Kosmas, C., Yassoglou, N., Moustakas, N. and danalatos, N.G. (1`996). Field site Spata, Greece. Basic field programme. MEDALUS II . Final report. Medalus Office, Berkshire, UK, 129-163.

Le Houérou, (1990). Ecological guidelines to control land degradation in European Mediterranean countries. In

Rubio. J.L.and Rickson, R.J. [Eds] Strategies to combat desertification in the Mediterranean Europe. Comm.Eur. Comm. EUR 11175 EN/ES, 3311-360.

Llamas. M.R. (1997) Consideraciones sobre la sequia de 1991 a 1995 en Espana. Ingenieria del Aaqua 4, no1, 39-50.

Lopes-Bermudes, F., Tobar P., Javier Pardo,F and Romero, A. (1998). Regional economic and social approaches to desertification. MEDALUS III Regional indicators, second annual report 65-80.

McDonald, W.A. (1972). The problems and the program. In: W.A. McDonald and G.R. Rapp, Jr. (eds) The Minnesota Messinia Expedition. Reconstructing a Bronze Age regional environment. University of Minnesota Press. Minneapolis.

Rubio, J.L. (1995). Desertification: Evolution of a concept. In: R. Fantechi, D. Peter, P Balabanis and J.L. Rubio (eds). Desertification in a European context: Physical and socioeconomic aspects.

Runnels, C.N. (1995). Environmental degradation in ancient Greece. Scientific American, March: 72-75.

Tzedakis, P.C. (1993). Long term tree population in northwestern Greece through multiple climatic cycles. Nature, 364: 437-40.

UNCCD. (1997). United Nations convention to combat desertification in those countries experiencing serious drought an/or desertification, particularly in Africa. Secretariat of the Convention, Bonn, DPSD/CCD/97/1.

UNEP (1997). World atlas of desertification, second edition, Arnold.

Van Andel,T.H. and Runnels, C.N. (1987). Beyond the Acropolis. A rural Greek past. Stanford University Press, Stanford, California.

Van Wersch, HJ. (1972). The agricultural economy**.** In: W.A. McDonald and G.R. Rapp, Jr. (eds) The Minnesota Messinia Expedition. Reconstructing a Bronze Age regional environment. University of Minnesota Press. Minneapolis.

Van Overloop, E. (1986). Comparison of climatic evolution during the post-glacial times in Greece, tropical and subtropical regions, in relation to desertification. In R. Fantechi and N.S. Margaris [Eds] Desertification in Europe, Com. Eur. Comm., D. Reidel Pub. Comp., Dordrecht, 59-72.

Verheye, W.H. (1991) The role and impact of biophysical determinants on present and future land use patterns in Europe**. In:** F.B. Brouwer, A.J. Thomas and M.J. Chadwick (eds), Land use changes in Europe. Processes of change, environmental transformations and future patterns. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Yaron, B., Shalvet, J., Shimshi, D. (1973). Patterns of salt distribution under tricle irrigation. In A. Haadas, D. Swartzendruber, P.E. Rrijtema, M. Fuchs and B.Yaron [Eds] Physical aspects of soil water and salts in ecosystems. Springer-Verlag, New York, 389-394.

Yassoglou, N.J. and Nobeli, C. (1972). Soil studies. In: W.A. McDonald and G.R. Rapp, Jr. (eds) The Minnesota Messinia Expedition. Reconstructing a Bronze Age regional environment. University of Minnesota Press. Minneapolis.