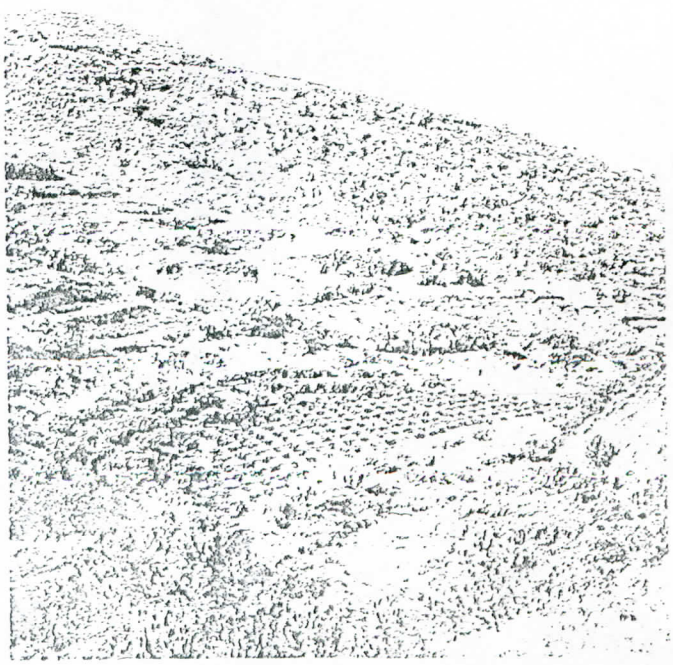
Commission of the European Communities

SOIL AND GROUNDWATER RESEARCH REPORT I

SOIL SURVEY – A BASIS FOR EUROPEAN SOIL PROTECTION



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CURRENT THREATS TO SOILS AND ECOSYSTEMS IN SPAIN

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INTRODUCTION

The environmental problems which affect Spanish land result from the Mediterranean climate, from many centuries of exploitation of ecosystems that are very susceptible to erosion and desertification, and from more recent ecological risks which arise from a society based on industrial development and technology. Some of these aspects of environmental deterioration are common to all of the countries in the European Community, but some are particularly serious in southern Europe and others are limited to the Mediterranean environment. This paper focuses particularly on the latter two situations, as they are least well known in the central and northern countries of Europe.

Erosion in Spain

There are several circumstances which favour the processes of erosion in the Mediterranean environment. Among these are the heavy rains which fall primarily in spring and autumn, when plant cover is sparse or absent after unfavourable winter or summer conditions. Mediterranean grazing land dominated by therophytes or scrub, often forming sparse cover, offers little protection. An extreme but not infrequent case is that of weather conditions characterized by *gota fria*, which typically occurs in autumn in the coastal zones of the Mediterranean sea and also in the temperate-humid climate of northern Spain. The rainfall within a few days, perhaps even in one day, may exceed the annual average. These rains seriously erode the soil, cause landslides, fill reservoirs with sediment, damage roadways and villages, and may even result in the loss of human life. Because of irregularities in the amounts and timing of rainfall from one year to the next, it is difficult to predict degrees of erosion realistically in Mediterranean environments using procedures such as those of the Universal Soil Loss Equation. Depending on particular circumstances, it is possible to lose more soil within a few days than in several years under a "normal" climate. For these reasons, new strategies are needed to deal with the processes of erosion. It should however also be pointed out that the continentality of a large part of Spain distinguishes it from other countries of southern Europe. Average annual rainfall and seasonal cycles differ considerably from one region to another within Spain.

Desertification

The most serious cases of desertification generally coincide with the areas of least precipitation and more rarely with areas of highest average temperature. In south-eastern Spain average annual precipitation can vary from about 300 mm to as little as 130 mm, for example as at Cap of Gata. There are thus desertified zones, and although they are not true deserts, their natural aridity has been sustained over thousands of years. We do not exclude the possibility of recent expansion of these zones into adjacent areas due to human or even natural causes (Gilman and Thornes 1983, Pou 1988). The typical arid character of these regions and their great richness in endemic species appears to indicate the antiquity of their communities. The interest of these unique ecological localities should not, however, detract attention from the threat of desertification throughout the country as a whole. In summary, the Spanish regions where desertification may increase due to human causes are in the south-east (in the provinces of Murcia, Almeria, Granada and Alicante), in the north-east (in parts of the central Ebro basin) and on the eastern-most islands of the Canary archipelago.

Human Factors

Independent of the climatic and physiographic factors man's activities are also significant in the processes of desertification within Spain as throughout the Mediterranean basin. The littoral regions of the Mediterranean are among those with the longest history of human population. A large part of this territory has suffered intense deforestation. On mountainous slopes, the soil has had little protection as it has been covered with Xerophytic pastures or scrub which provides only limited ground cover. Consequently erosion has produced an irreversible loss of soil which is evident in the extent of rock outcrops. Some areas suitable for cultivation have suffered less damage because of terraced farming, which has checked erosion. Farmers too have restored some of the destruction caused by intense rains and run-off. Recently the movement of workers from agricultural regions

to industrial centres which began in the 1960s, has left the poorest zones of the countryside depopulated. As a result, many of the terracing systems have been allowed to degenerate, leading to renewed erosion.

Another important factor has been the use of fire as a traditional pastoral practice to eliminate scrub and weeds as well as to fertilize the soils. This activity has generally produced good results, but has also left the soil without vegetation at times of heavy rainfall. In addition, compaction of the soil by excessive pasturing has increased the erosive processes.

Periodic socio-economic crises caused by wars or epidemics have also added to the intensive exploitation of the land. For example, after the Spanish Civil War this century, the economic crisis, aggravated by the political isolation of Spain under the dictatorship, produced a widespread famine that led to the cultivation of mountainous slopes which otherwise would have remained undisturbed.

The vegetation of the Mediterranean region includes diverse types of forest stands, although sclerophyllous formations *(Quercus ilex, Q. rotundifolia* and *Q. suber)* are the most characteristic (Peinado and Rivas-Martinez 1987). More than three-quarters of the Mediterranean region of the peninsula is potentially of this type. In spite of their great potential extension, the sclerophyllous forests have suffered major regression due to both exploitation for agriculture and grazing, and afforestation by conifers and eucalypts. Extensive agriculture has been practised above all in areas of warm climate, calcareous substrate and favourable topography (for example in the Castillian plateau, Andalusia and along the Mediterranean coasts). Pastoral use of the land has been predominantly in areas of poor siliceous soils, often shallow, in the middle western region of Spain. In the latter case, a typically Mediterranean system of sylvo-pastoral use has been practiced, the *dehesa* (Ibanez *et al.* 1989).

The scarcity, periodic and torrential nature of rainfall in these territories linked with the slow rate of soil formation and the difficult regeneration of vegetation after human exploitation, combined with the brittle nature of some rock create a situation in which the semi-arid and arid ecosystems of the Iberian peninsula are those which are at the greatest risk of erosion and desertification.

The semi-deciduous forests of *Quercus pyrenaica* and *Q. faginea* displace sclerophyllous species in regions less droughty in summer. These too, however, possess a clear Mediterranean character. They are principally developed in the subhumid (600–1000 mm mean annual precipitation) and humid (1000–1600 mm) supra-Mediterranean climates (see Rivas-Martinez (1983) for definition of climatic zones) of the middle northern Mediterranean region of Spain. More rarely, they also descend to meso-Mediterranean levels of similar ombro-climatic character. The *Q. pyrenaica* forests are developed on acid soils, the *Q. faginea* forests on eutrophic or calcareous substrates. Grazing and afforestation have been the principal systems of use within their potential distribution. The richest soils, originally under *Q. faginea* stands, have also been used agriculturally in areas with favourable climate and topography.

The development of tourism initiated in the 1960s (forming one of the principal sources of revenue for the Spanish economy), has resulted in the destruction of nearly all the natural vegetation of the Mediterranean coastal peninsula. In the face of this problem, the Spanish governments have lacked the knowledge or the desire, to adopt the measures necessary to protect these threatened ecosystems. The serious loss of sand from the beaches should also be mentioned here. This has been a consequence of the inland retention of continental sediments by reservoirs, the check on the accretion of beach sands caused by the creation of embankments for recreational ports and the removal of beach sands for greenhouse sand cultivation.

In recent years changes in land use have been encouraged by EC policies, without an exact knowledge of the ecological structure and function of Mediterranean soils and ecosystems. Such changes alter the processes which control the edaphic system's capacity for self-regulation, producing among other things, populations of pathogenic agents that diminish their productive capacity (Bello *et al.* 1989). At the same time, agricultural techniques being used to exploit the soil are changing, in very different ways in the various regions.

In middle western Spain, human adaptation to the environment and the less dense self sufficient population has resulted in a system of agricultural–pastoral–forest use of great ecological interest, which could be exported to other regions with semi-arid environments. Unfortunately, these so-called *dehesas* are in danger of extinction due to the rapid socio-economic changes of the last few decades and the indifference of the Spanish administration toward the modernization of these productive systems.

In the middle eastern region of the Iberian peninsula, the oldest settled commercial region, there are ecosystems in which the vegetation is especially adapted to grazing, logging and periodic planned burning. When these practices cease or diminish in intensity, because of depopulation or the opportunity for employment in industry or tourism, a great deal of combustible material tends to accumulate. In this way, spontaneous or intentional burning results in more serious damage under traditonal practices. Thus, the soil suffers greater risks of erosion.

Finally, another serious problem in the Mediterranean basin deserves mention: the salinization of agricultural soils. The principal causes of this process appear to be the over-use of water reserves near the coast and inadequate irrigation policies in some areas. Obviously, these problems become even more serious where the climate is becoming more arid.

According to data obtained in a joint study by the General Office of the Environment (Ministry of Public Works and Urban Planning (MOPU)) and the National Institute of Nature Conservation (ICONA 1987) 16.5 per cent of Spanish territory suffers a very high degree of erosion, while 27.5 per cent suffers moderate erosion. Analysis of the erosion estimates for the main river catchments reveals that 65.7 per cent of the Guadalquivir, 52.4 per cent of the Ebro and 41.4 per cent of the Tajo basins exceed loss levels of 12 tonnes ha^{-1} yr^{-1}. Within the Guadalquivir basin, 24 per cent of the land shows degrees of erosion on the order of 100 to 200 tonnes ha^{-1} yr^{-1}. Data compiled by ICONA for the different autonomous communities within Spain show that erosion seriously affects more than 30 per cent of the land surface in the communities of Murcia, Andalucia, Castilla-La Mancha and Madrid, between 20 and 30 per cent in Aragon, Extremadura, Valencia and the Canary Islands, between 10 and 20 per cent in Asturias, Navarra, La Rioja, Catalonia, Castilla-Leon and the Balearic Islands, and less than 10 per cent in Galicia, Cantabria and the Basque Country. Clearly, erosion becomes more intense towards the south and east (Fig. 1).

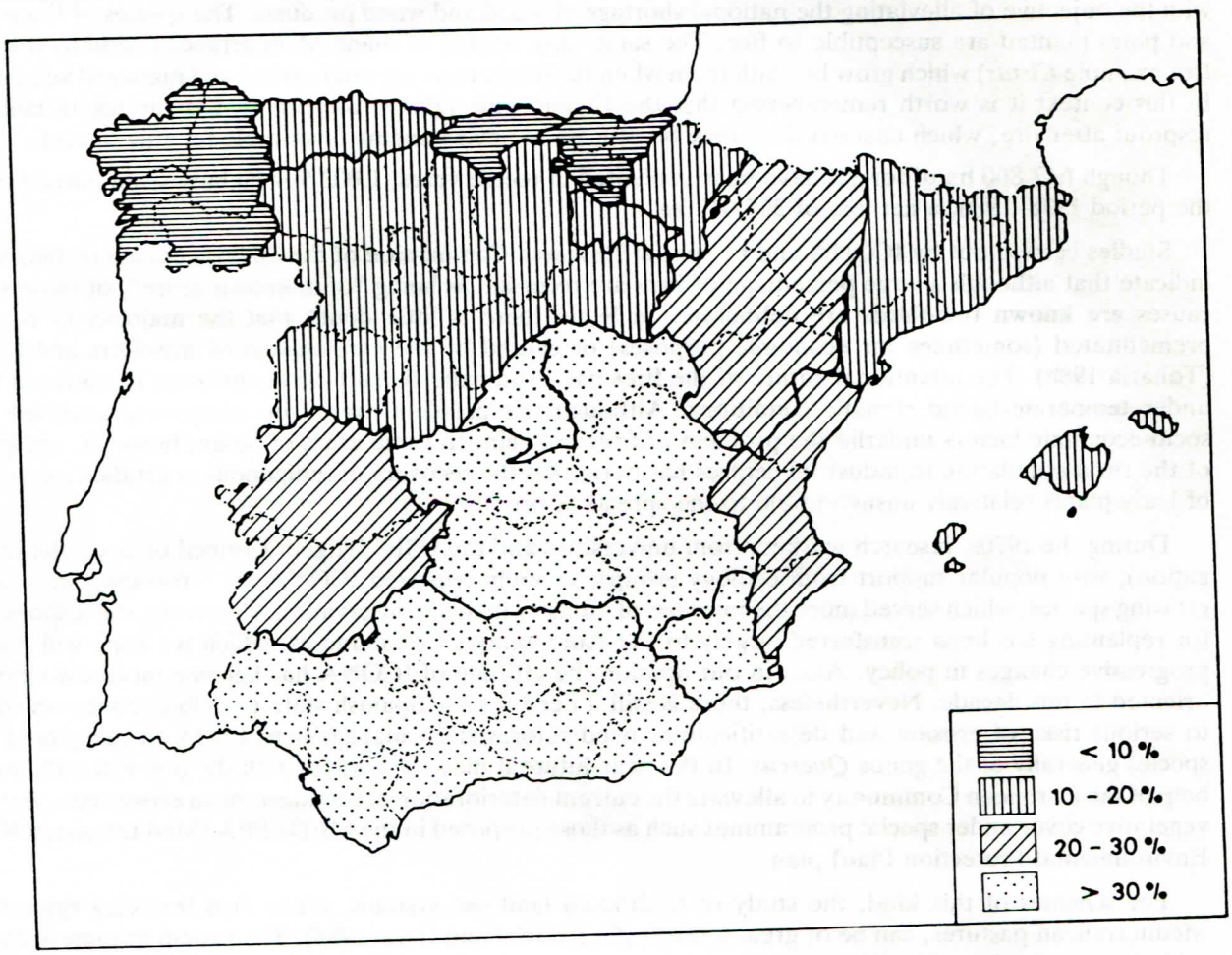

Fig. 1 Percentage of land affected by soil erosion by autonomous communities

Nationally 30 per cent of land surface area suffers serious erosion, 45 per cent faces moderate to serious erosion and 25 per cent is not seriously threatened (Toharia 1988). For Spain as a whole, the amount of eroded soil exceeds 1,000,000 tonnes yr^{-1}.

As an example, serious erosion processes affect more than 75 per cent of the province of Murcia and 67 per cent of Andalusia (Toharia 1988). In these areas, soil losses of up to 500 tonnes ha^{-1} yr^{-1} and intense rains

of 60 litres m^{-2} h^{-1} have been measured where grapes and almonds are cultivated, figures which are not the most extreme recorded. Similarly, Perez-Soba and Barrientos (1988) calculated that 76 per cent of the area studied in the LUCDEME project showed soil losses greater than 10 tonnes ha^{-1} yr^{-1}.

Obviously soil erosion is much more serious for Mediterranean ecosystems than for those of northern Europe, even when management techniques are as carefully applied. For this reason, changes in land use or land management should be undertaken with greater precautions than in northern Europe. This implies some further hindrance to economic growth, when the lesser degree of industrial development in southern Europe is taken into account.

The Struggle Against Erosion and Desertification in Spain

In the last few decades, the administrative body responsible for restoration and conservation of river catchments (ICONA, and former equivalent institutions) has applied a considerable effort to reforest large areas of Spanish terrain. Unfortunately the net result has been failure. There are several reasons for this. One which deserves mention is that afforestation has been with species of rapid growth (generally pines and eucalypts) with the objective of alleviating the national shortage of wood and wood products. The species of Eucalyptus and pines planted are susceptible to fire. The same may be said of many Mediterranean scrubland species (for example *Cistus*) which grow beneath them when the plantations are not brashed and managed adequately. In this context it is worth remembering that the Canary pine *(Pinus canariensis)* has the useful ability to resprout after fire, which characteristic may be utilized in environments favourable for this species.

Though 647,860 ha of forests have been replanted in recent years, 1,002,907 ha have been burned during the period 1978–1986, a net loss of 355,047 ha.

Studies carried out by ICONA and by special Research Commission of the Spanish Senate in 1988 would indicate that although a large percentage of fires are recorded as being "of unknown cause", of those whose causes are known two-thirds are deliberate. In Spain there is little doubt that the majority of fires are premeditated (sometimes for economic purposes) or caused by the carelessness of travellers and tourists (Toharia 1988). The intentional nature of the fires has a dramatically surprising character in northern Spain under temperate-humid climatic conditions. Although this problem cannot be adequately analysed here, socio-economic factors underlie the problem of fires in Spain. In some areas of Spain, however, emigration of the rural population to industrial centres has permitted the recovery of indigenous vegetation, sometimes of leafy plants relatively unsusceptible to the spread of fire.

During the 1970s, research workers from universities and the CSIC (Higher Council of Scientific Investigation), with popular support from ecology groups, severely criticized ICONA for reforesting with rapidly growing species, which served more the interests of industry than of conservation. Currently, the responsibility for replanting has been transferred largely to the Autonomous Communities, which we hope will produce progressive changes in policy. Also, in our opinion the attitude of ICONA has become more conservation-oriented in this decade. Nevertheless, there is still a need for the Spanish state to delimit zones which, due to serious risks of erosion and desertification, need reforestation management based on indigenous leafy species generally of the genus *Quercus*. In the near future it may be possible with the political and financial help of the European Community to alleviate the current deterioration of Mediterranean ecosystems, installing vegetative cover under special programmes such as those proposed in the MEDESPA (Mediterranean Region Environmental Protection Plan) plan.

For schemes of this kind, the study of traditional land use systems, other than terracing systems and Mediterranean pastures, can be of great interest (Gomez Sal and Bello 1983). The system in some areas with arid climates (such as the coastal fringes of Almeria and the Canary Islands) of the creation of *sand crops* and ground cover is of interest. This traditional system has been improved progressively by incorporation of new technology, to the point where today it may be one of the most profitable and productive agricultural systems in Spain, in spite of climatic conditions.

There are other agricultural systems in the Canary Islands which are useful in combating the desertification process (Rodriguez *et al.* 1989). Some traditional Canary Island techniques involve the preferential use of some volcanic materials in a basic strategy against aridity and erosion. Between the volcanic lava flows there are fissures (or cracks) with outcrops of paleosols with microclimatic conditions that are very favourable for cultivation. Also of great interest are the systems of soil formation, as in the *jables* (grooves) of southern Tenerife and sand cultivation on the island of Lanzarote (Rodriguez *et al.* 1989). These are agricultural systems of great originality, of aesthetic interest and of scientific importance in the struggle against desertification.

New technologies, therefore, are needed to maximize the efficiency of these systems. Among the available new technologies, conservation cultivation deserves mention. This has been applied chiefly in cereal grain and fruit cultivation, with very positive results in the struggle against erosion.

The problems of erosion and desertification in Spain have been reported since the Nairobi International Conference held under the auspices of the United Nations Organization in 1977. It was after this conference that the Government began the first efforts to investigate possible ways of combating desertification, but only recently has the gravity of the situation come to be appreciated. Currently, the media as well as those responsible for scientific policy are reporting almost daily on the extent of the problems and on the grave ecological, economic and social risks involved. Because of the wide interest, there has been an increase in the number of monographs translated into Spanish and a proliferation of books which deal with related topics. Spanish scientists, especially those working in coastal Mediterranean regions, have recently published their results in international scientific journals (see for example, the first issues of *Soil Technology*).

Clearly, the affiliation of Spain to the European Community has increased interest on the part of the Community in the problems of erosion and desertification. This is logical as Spanish territory is most affected by these processes. Consequently, the Informal Council of Environmental Administration of the European Community, which met May 5–7 1989 under Spanish chairmanship in the Spanish city of Caceres prepared a document which affirmed interest and concern about environmental destruction and erosion in EC Mediterranean countries. At this meeting, the Council President, the Spanish Minister J.L. Saenz de Cosculluela remarked that "the struggle against the effects of soil erosion and desertification in European Community zones constitutes a new dimension in community environmental policy".

For all the above reasons its not surprising that the Spanish Interministerial Commission of Science and Technology, in the recently approved National Programme of Conservation of Natural Resources and Processes of Environmental Destruction, proposed that the processes of desertification and erosion be considered as scientific and technological priorities.

In parallel, the CSIC, together with the Government of the Autonomous Community of Valencia, have created a joint "Desertification Studies Department" in the Agrochemistry and Food Technology Institute of the CSIC in Valencia.

After the Nairobi Conference, the Ministry of Agriculture, Fishing and Food, through ICONA, prepared a paper in May 1978 on "The problem of erosion: Programme of action on the Mediterranean slope". Along the lines of the "Nairobi Plan of Action", with co-operation at regional level, a ministerial directive October 5, 1981 entrusted ICONA the task of developing the LUCDEME programme. This programme was put into effect in 1983 and involves a large number of researchers from different institutions including CSIC, universities and ICONA. Their area of study (30,000 km^2) is the seriously affected land of the south-eastern peninsula.

Worries about the struggle against erosion and desertification later led to inclusion of protective measures in the new Water Law of 1985, which in its Article 41 enumerates those aspects which must be included in hydrological plans.

Parallel to the LUCDEME programme, ICONA has carried out diverse studies of erosion in Spain. Among them has been the creation of a national database on erosion. Recently, "Maps of Erosive States" have been published for the major river catchments of the peninsula at 1:400,000 scale (the database has been tabulated at larger scales (minimum 1:200,000).

Despite these events and the efforts of some Autonomous Communities to initiate desertification and erosion studies in their own territories, only the recently-approved CICYT programme has opened this area of investigation in conjunction with the universities and with CSIC. To date, no national investigative teams have been established nor has adequate funding been budgeted to deal with this serious matter rigorously enough.

The problems of desertification and soil conservation are a common inheritance of all countries of the European Community, but, in the authors' opinion, a line may be traced, dividing the map of the Community into two regions with differing problems. In central and northern European countries, the acid rain problem is most serious. In the Mediterranean countries (especially Spain, Italy and Greece) the risk of desertification due to soil erosion is the predominant problem. If we view desertification as a diminution or destruction of the land's biological potential, the Mediterranean region could be subdivided into a series of zones taking into account the likely qualitative regeneration response after complete erosion of the soil. Seen from this perspective and considering current climatic conditions, only arid and semi-arid regions are threatened by the formation or advance of desertization zones. In other words, a large part of the Mediterranean region of the EC does not face serious desertification; the more salient threat in these regions is the replacement of sclerophyllous or semi-deciduous forests by shrublands or scrublands of *garriga* or *maquia* type.

Obviously these sorts of qualitative changes in the processes of ecological succession require additional paleoecological studies to demonstrate changes in vegetation since the last glaciation. In this sense, studies on the current risks and degrees of erosion are not decisive, even though they contribute valuable information. The investigative teams capable of pursuing these subjects would have to be highly interdisciplinary and with the ability to coordinate their efforts.

The socio-economic repercussions of erosion and desertification depend to a large extent on a country's degree of economic development. Certainly the economic evaluation of these processes is difficult, but they could amount to a permanent restraint on economic growth in several Mediterranean countries which are faced with an environmental situation less favourable than that of their currently more industrialized neighbours to the north. Nonetheless because of our technological development and our capacity to intervene, the current problem does have the same dramatic consequences as in the Third World. Only in the case of a severe economic recession would we face a problem of great socio-economic magnitude (Pou 1988).

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