# Land resources - contents

# 1. Framework and objectives of the project

## 1.1. The CORINE programme

### 1. 1. 1. Objectives

### 1.1.2. Content and implementation

### 1.1.3. Results of the programme

# 1. 1. 1. Objectives

Since the establishment of the European Community environment programme in 1973, the need to improve knowledge about the environment has been apparent. Better information is needed on the state of the environment, its evolution and the reasons for change, not only at the national or regional level but also at the Community and international level.

Since that time, much work has been done to improve the situation. Numerous programmes have been set up to collect data, monitor environmental conditions and produce inventories. Almost without exception, however, these programmes have been developed on a case-by-case basis, aimed at solving specific problems. As a consequence, these programmes have in some cases duplicated each other, and resulted in a waste of effort and resources. In addition, the lack of coordination has meant that they have typically used different methods of data collection or measurement, different nomenclatures, and different sampling procedures. This in turn means that the data themselves are often inconsistent from one country - and even from one region - to another.

The implications of this situation are serious. lt is clear that - to be able to determine the direction of environmental policy, to be aware of the effects of that policy, and, above all, to integrate an environmental dimension into other Community policies - it is essential to have a clear and reliable understanding of the environment. This must encompass all those aspects which influence policy: the state and distribution of natural habitats and wildlife; the quality of soil and water resources and their uses; the character and quantity of harmful substances discharged into the environment; and any natural risks which must be taken into account in the process of land management.

In response to this need, the European Commission undertook a series of preparatory works which led the Council of Ministers to adopt a decision on a Commission work programme - the CORINE programme - comprising an 'experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community' (European Communities, 1985a).

Initially planned to run for four years, the programme was subsequently extended by two years to provide a bridge to the newly agreed European Environment Agency (European Communities, 1990a).

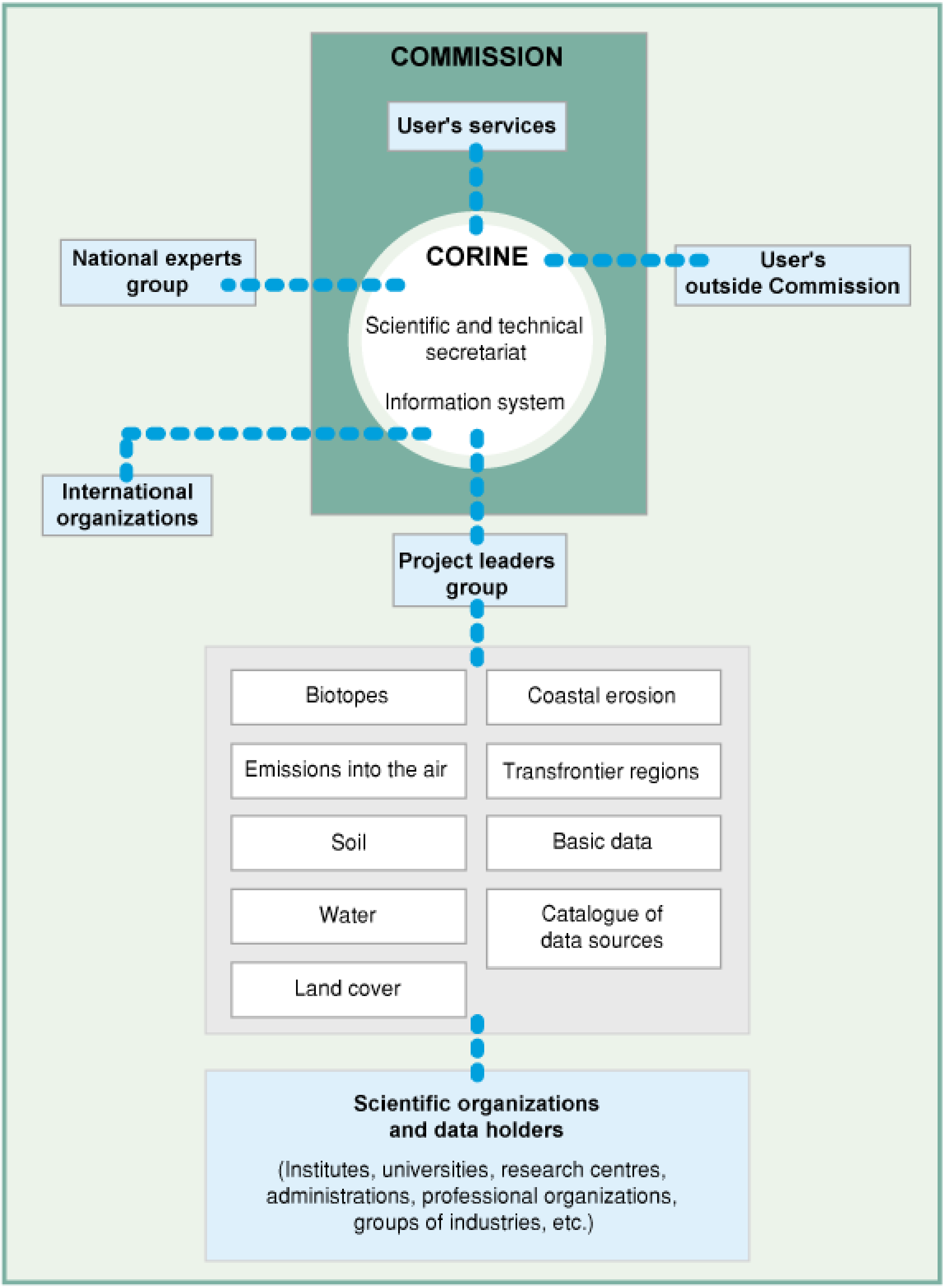
As defined in the Council Decision, the CORINE programme involved three complementary objectives:

(i) to help guide and implement Community environment policy, and to help incorporate an environmental dimension into other policies, by providing information on priority topics;

(ii) to help ensure optimum use of financial and human resources by organizing, influencing and encouraging initiatives by international organizations, national governments or regions to obtain environmental information;

(iii) to develop the methodological base needed to obtain environmental data which are comparable at a Community level.

Fig 1.1 - Structure and organization of the CORINE programme



## 1.1.2. Content and implementation

Implementation of the CORINE programme clearly involved the use of both new and developing technologies (e.g. GIS) and an extremely wide and diverse area of expertise (covering almost all sectors of the environment). To focus attention and structure the work, therefore, the Council Decision identified the following set of priorities:

(i) an inventory of biotopes of major importance for nature conservation;

(ii) collating and making consistent data on acid deposition, and, in particular, the establishment of a cadastral survey of emissions into the air;

(iii) the evaluation of natural resources and environmental problems in the southern part of the Community (e.g. soil erosion, water resources, land cover, coastal problems), with especial regard to those areas which are eligible for support from the structural Funds;

(iv) work on the availability and comparability of data.

In order to carry out the programme, the Commission - with the support of a committee of national experts (the national experts group) - established a series of specialized technical teams, each concerned with one of the specific priority areas. These teams were responsible for developing appropriate methods of data collection and analysis, collecting the appropriate data, and validating the results, under the guidance of a technical and scientific secretariat (Figure 1.1).

**Table 1.1 - The CORINE database - Summary of contents**

## A - The geographic base

## B - Nature

## C - Land

## D - Air

## E - Water

## F - Socio-economic data

## Table 1.1. A - The geographic base

| Theme | Nature of the information | Volume of information description | Mbytes | Resolution/ scale |
|---|---|---|---|---|
| Coastline and national boundaries | Coastline and national boundaries (Community and adjacent territories) | 62 734 km | 0.3<br>3.2 | 1/3 000 000<br>1/1 000 000 |
| Administrative units | EC NUTS regions (Nomenclature of territorial units for statistics)<br>4 hierarchical levels | 829 NUTS-regions digitized | 0.8 | 1/3 000 000 |
| Administrative boundaries | SOEC localities database extending NUTS to level IV and level V (communes) | Benelux countries:<br>1 421 communes | 1.5 | 1/500 000 |
| Water pattern | Navigability, categories (rivers, canals, lakes, reservoirs) | 49 141 digitized river segments<br>983 digitized river segments | 13.8<br>0.3 | 1/1 000 000<br>1/3 000 000 |
| Slopes | Mean slope per km' (southern regions of the Community) | 1 value per $km^2$, i.e.<br>800 000 values | 45.0 | 1/100 000 |
| Settlements | Name, location, population of urban centres > 20 000 inhab. | 1 542 urban centres | 0.1 | Location of centre |
| World map | Coastlines, country boundaries and rivers (planet) | 196 countries | 1.5 | 1/25 000 000 |
| Transport network | Road coverage EC + CH, A | 27 050 road segments | 6.5 | 1/1 000 000 |

## Table 1.1. B - Nature

| Theme | Nature of the information | Volume of information description | Mbytes | Resolution/ scale |
|---|---|---|---|---|
| Biotopes | Location and description of biotopes of major importance for nature conservation in the Community | 5 600 biotopes described, according to approx. 20 characteristics | 20.0 | Location of the centre of the site |
| | | Boundaries of 440 biotopes computerized (Portugal, Belgium) | 2.0 | 1/100 000 |
| Designated areas | Location and description of areas classified under various types of protection | 13 000 areas described according to approx. 11 characteristics(file being completed) | 6.5 | Location of the centre of the site |
| | | Computerized record of the limits of the areas designated in compliance with Article 4 of Directive 409/79/EEC on the conservation of wild birds | | 1/100 000 |
| Natural potential vegetation | Mapping of 140 classes of potential vegetation | 2 288 homogeneous areas | 2.0 | 1/3 000 000 |

## Table 1.1. C - Land

| Theme | Nature of the information | Volume of information description | Mbytes | Resolution/ scale |
|---|---|---|---|---|
| Soil types | 320 soil classes mapped | 15 498 homogeneous areas | 9.8 | 1/1 000 000 |
| Climate | Precipitation and temperature (other climatic variables: some data incomplete) | Mean monthly values for 4 773 stations | 7.4 | Location of station |
| Land quality/ important land resources | Assessment of land quality by combining four sets of factors: soil, climate, slopes, land improvements | 170 000 homogeneous areas, southern regions of the Community | 30.0 | 1/1 000 000 |
| Soil erosion risk | Assessment of the potential and actual soil erosion risk by combining four sets of factors: soil, climate, slopes, vegetation | 180 000 homogeneous areas, southern regions of the Community | 40.0 | 1/1 000 000 |
| Coastal erosion | Morpho-sedimentological characteristics (four categories), presence of constructions, characteristics of coastal evolution: erosion, accretion, stability | 17 500 coastal segments described | 25.0 | Base file: 1/100 000 Generalization: 1/1 000 000 |
| Land cover | Inventory of biophysical land cover, using 44 class nomenclature | Vectorized database for Portugal, Luxembourg | 51.0 | 1/100 000 |

## Table 1.1. D - Air

| Theme | Nature of the information | Volume of information description | Mbytes | Resolution/ scale |
|---|---|---|---|---|
| Emissions into the air | Tonnes of pollutants (S0,,N0x,VOC) emitted in 1985 per category of emission: electric power station, industry, transport, nature, oil refineries, combustion | 1 value per pollutant, per category of emission and per region, plus data for 1 400 sources i.e. +/- 200 000 values in total | 2.5 | Regional (NUTS III) and location of large emission sources |

## Table 1.1. E - Water

| Theme | Nature of the information | Volume of information description | Mbytes | Resolution/ scale |
|---|---|---|---|---|
| Water resources | Location of gauging station, drainage basin area, mean and minimum discharge, period:1970-85, for the southern regions of the EC | Data recorded for 1 061 gauging stations, for 12 variables | 3.2 | Location of gauging station |
| Surface fresh water quality | Annual values for 18 parameters, 1 1 3 stations, for 1976-86, supplied in compliance with Directive 77/795/EEC | 2 034 records/year | 0.2 | Location of station |

# Table 1.1. F - Socio-economic data

| Theme | Nature of the information | Volume of information description | Mbytes | Resolution/ scale |
|---|---|---|---|---|
| Socioeconomic activities | Statistical series extracted from the SOEC-Regio database. | Population, transport, agriculture, etc. | 40.0 | Statistical units NUTS II and NUTS III |
| Air traffic and airports | Name, location of airports, type and volume of traffic (1985-87). | 254 airports | 0.1 | Location of airport |
| Nuclear power stations | Capacity, type of reactor, energy production. | 97 stations, update 1985 | 0.03 | Location of station |
| Areas designated under Community | Eligibility for the structural Funds<br>Eligibility for the Interreg-initiative | 309 regions classified<br>219 regions classified | 0.01<br>0.01 | Eligible regions<br>NUTS regions |

### 1.1.3. Results of the programme

Within the context outlined above, the CORINE programme had two main aims:

(i) to verify the usefulness of a permanent information system on the state of the environment as a basis for Community environmental policy, to check the technical feasibility of creating such a system, and to identify the conditions required for its installation and operation;

(ii) to supply information useful for Community environmental policy in the specified areas of priority concern (biotopes, acid deposition, the Mediterranean region).

With respect to the first of these aims, results of the programme show that a permanent information system on the statc of the Community environment is both necessary and technically feasible. Moreover, the programme has enabled the conditions necessary for establishment and operation of such a system to be precisely defined.

The second aim of the programme has also been successfully achieved. Data on the priority areas have been collected, supplemented by and derived from a series of basic data. These data have been integrated into an operational geographic information system. Table 1.1 summarizes the scope and content of the information system.

In the light of these results, the Council of Ministers for the Environment agreed in 1990 to transform the CORINE prototype into a permanent information system within the framework of a European Environment Agency (European Communities, 1990b). This Agency will be supported by a European environment information and observation network. One of its main tasks will be to continue to supply the Community and its Member States with objective, reliable and comparable information on the state of the environment, in particular by taking advantage of the experience gained with the CORINE programme and by developing further the CORINE information system.

## 1.2. The CORINE project on soil erosion risk and important land resources in the southern regions of the European Community

> 'Land: an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man' (FAO, 1976).

## 1.2.1. Land resources and soil erosion:an issue of concern at the interface of Community and national policies

The rational management of land resources represents one of the most important and challenging policy issues in the European Community. It is an issue which is relevant at both the national and international level. It is an issue, also, which cuts across many different policy interests - environment, agriculture, rural and regional development - each of which both influences, and is affected by, the nature and problem of land resources. It is an issue the importance of which has been stressed on a number of occasions by the European Parliament.

The land is a vital resource, most notably for food production. It is also a vital component of many natural systems: habitats and ecosystems, the hydrological cycle, the landscape. It interacts similarly with the atmosphere and thereby influences the local and regional climate. Land conditions thus affect the state of the environment in many different ways. Yet land resources are both finite and susceptible to damage. The land is also quickly damaged yet slow to repair. Misuse of the land therefore can - and in many cases does - impair its value as a resource, and cause damage to the wider environment. Conservation of land resources, and the development of sensitive policies for their management, are consequently essential concerns.

These concerns are especially acute in southern regions of the European Community. Here, high quality land is scarce - limited by a range of physical and historic factors including:

(i) the irregular terrain and steep slopes;

(ii) drought and an uneven seasonal distribution of rainfall (with most intense rainfall often occurring in non-vegetative periods);

(iii) soil limitations such as shallowness, stoniness, unstable structure and chemical deficiencies;

(iv) long periods of past misuse which have degraded the soil fertility and encouraged soil erosion.

The better quality land that remains is often scattered and localized, confined in many cases to alluvial plains, valleys and basins. These same areas are also those which today experience the greatest pressures from land use. Urban development represents a particular threat, because the conditions of level terrain, favourable climate and deep, stable soils which make the land suitable for agriculture also create ideal sites for construction. In coastal areas, especially, tourism is leading to rapid urban growth. Yet agriculture, too, threatens the land.

Encouraged in recent decades by the European Community's own agricultural policy, intensification has caused changes n farming practices which may damage the soil. For example:

(i) increased mechanization and the use of heavy machinery;

(ii) lack of maintenance, or degradation, of terraces and ditches;

(iii) emoval of field boundaries and an increase in field size;

(iv) terrain levelling;

(v) monoculture and continuous cultivation;

(vi) reduced levels of manuring;

(vii) careless or excessive ploughing, sometimes up-and-down slope; and

(viii) changes in cropping practice

have together acted to cause soil compaction, a loss of soil organic matter, a reduction in structural stability, increased rates of erosion and soil loss, and disturbance to the soil ecosystem.

The extent of soil erosion has until now been difficult to assess, for consistent data have been scarce. Grazziani (1988) attempted to give some indication of the scale of the problem. He suggested that 25% of the land area of Greece, and 22% in France, was affected by serious erosion, while 62% of Italy had a potential erosion risk. Other data, collected by UNEP, are shown in Table 1.2. As a result of the project reported here, however, better estimates can now be made. General results are given in Figure 1.2.

The effects of soil erosion on both land resources and the wider environment are wide-reaching and serious. The most direct consequence is a loss of productivity and reduced yields: in the short term due to the removal of seeds and fertilizers and damage to the standing crop; in the longer term due to loss of the topsoil, increased stoniness and diminished rooting depth. The secondary effects

include increased rates of siltation in streams and reservoirs, and pollution of water caused by fertilizers and pesticides attached to the soil particles. In addition, the damage to the vegetation cover, and the associated increase in albedo and change in local climates, may encourage desertification. Again, information is scarce, but data compiled by the UN indicate that as much as 200 000 km, of the Mediterranean region
may be subject to desertification, mainly in Spain and Greece.

Figure 1.2 - Extent of current (actual) soil erosion in southern Community countries

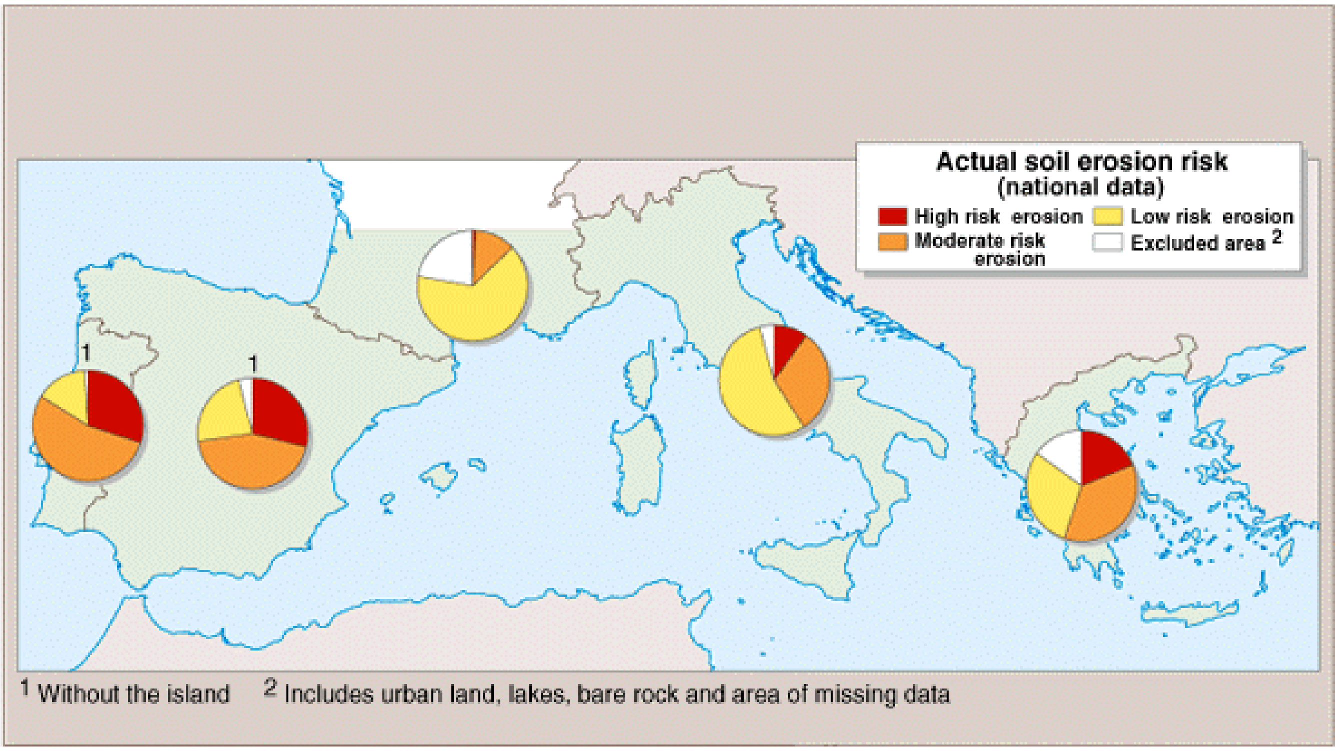



Table 1.2 Sediment loads in selected rivers in southern Community countries

| **River and country** | **Watershed area (km2)** | **Turbidity (kg/m3)** | **Mean annual load to the sea** (1 000 t sediments) | **Average sediment load to the sea** (t/km2) |
|---|---|---|---|---|
| Axios, Greece | 23 | 189 | 206 | 35 |
| Po, Italy | 70.10 | 405 | 14 417 | 206 |
| Rhone, France | 95.60 | 34 | 1 625 | 17 |
| Jucar, Spain | 21.50 | 62 | 79 | 4 |
| Drin river, Albania | 12.40 | 1 250 | 13 412 | 1 082 |

***Source:*** UNEP, 1987.

### 1.2.2. State of the art

#### 1.2.2.1. Land quality

#### 1.2.2.2. Soil erosion risk

## 1.2.2.1. Land quality

In the light of the increasing concern about land resources in Mediterranean countries, it is not surprising that a number of attempts have been made over the last 30 years to evaluate and map land quality and soil erosion risk. In the case of land quality, two approaches have generally been followed:

(i) either the assessment of land capability (i.e. the broad potential of the land for sustained agricultural use), often with the aim of soil erosion control; or

(ii) the assessment of land suitability, with the objective of defining the productivity or potential of the land for specific crops or other uses.

Many examples can be quoted of the use of these approaches to map land quality, including the work of Direccion General de la Produccion Agraria (several years) in Spain; Centro Nacional de Reconhecimento e Ordenamento Agrario (several years) in Portugal, Duclos (1980) in France; IPLA (1982), Lulli et al. (1980), Rodolfi (1986), Aquater (1977) and Ufficio Analisi Richerche Territoriali (1981) in Italy; and Nakos et al. (1980), Shahabi (1982) and Yassoglou et al. (1971, 1983) in Greece.

Whilst these surveys have often produced assessments of land quality at the regional or national scale, however, their ability to meet more general environmental policy needs is limited. They are neither comprehensive in their geographical coverage nor uniform in their methodology. Most have also been designed for specific land and management systems, so cannot easily be extrapolated to new areas or applications. On the other hand, broader scale evaluations of land quality are generally lacking.

In the light of this situation, the Agricultural Directorate of the European Commission did establish a research programme on land use, from 1984 to 1988, which has given rise to a number of detailed studies. Members of this research group have also collaborated closely in the development of the CORINE programme. In addition, as part of the preparatory work for the CORINE programme, a project was set up to investigate methods of mapping biomass potential at the Community level (Briggs, 1983). Although subsequently used to assess the potential impacts of COI-induced climatic change on biomass production (Briggs and Coleman, 1984), this survey provides only a broad-scale assessment for the previous 10 Member States. Prior to the present study, therefore, no comprehensive yet reasonably detailed analysis of land quality existed for the Mediterranean region.

Table 1.3 Examples of maps of soil erosion in southern Community countries

| Type of erosion | Title | Author | Year | Scale | Area investigated | Main parameters considered | Data sources and methods |
|---|---|---|---|---|---|---|---|
| Present soil erosion by water | Estimación de la erosión y aterramientos de embalses | Bermúdez, et al. | 1982 | | Watershed of Rio Segura (Spain) | Sedimentation data<br>Index of climatic aggressivity (Turc)<br>USLE | Experimental records and climatological data |
| Present state of soil erosion, landslides and mass movements | Carta geologica e del dissesto | Aquater | 1977 | 1:500 000 | Mountain areas (Italy) | Landslides<br>Mass movements<br>Erosion | Bibliography or aerial photographs |
| | Carta della stabilita dei versanti | Regione Emilia Romagna | 1980 | 1:25 000 | Emilia Romagna region (Italy) | As above | Direct survey or aerial photographs |
| Present state of soil erosion: landslides, mass movements, geomorphological hazards | Geomorphological mapping and soil conservation in the disadvantaged areas in north-central Appennines | Rodolfi | 1986 | 1:20 000 and 1:15 000 | Watershed of Torrente Diaterna Florence (Italy) | Morphology<br>Soils | Morphological survey<br>Soil survey |
| Soil erosion risk (quantitative evaluation) | Carte de 1'érosion hydrique potentielle | Cadeville-Levy | in press | 1:2.5 million | France | Slopes<br>Superficial formations | Topography and geomorphology map |
| | Map of susceptibility to soil erosion (8 classes) | Maduegño | 1987 | 1:1 million | Provinces of Seville Cordoba and Jaen (Spain) | Soil erosion expectations (USLE; t/ha/yr)<br>Soil erosion tolerance | Rainfall data<br>Soil map and regional information |
| | Wind erosion risk (5 classes) | Quirantes, et al. | 1987 | 1:400 000 | Area located between Granada and Murcia (Spain) | Silt, clay and gravel | Laboratory analyses |
| Various | Lucdeme Project | Icona | 1982 | 1:500 000 | South-east of Spain | Erosive landscape<br>Accumulated damages<br>Drainage network evolution<br>Erosion degree<br>Annual soil losses | Geomorphology and vegetation<br>Eroded surfaces percentage and coefficient for erosion type<br>Aerial photographs with 20-year interval<br>Matrix that combines actual erosion and drainage network<br>Wischemeier's USLE |
| Present water erosion rate | Mapa de estados erosivos (t/ha/year) | Icona | 1988 | 1:400 000 | Spain divided in main watersheds | Climatic aggressivity | Multiple correlation factor R and maximum rainfall with a return period of |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | two years |
| | | | | | | Soil | Regression model (texture, organic matter, permeability) |
| | | | | | | Topography | Method of Williams, et al. (1 976) |
| | | | | | | Slope length | Drainage network density |
| | Carta delle lince di ugual erosione progressiva media (mm/year) | Gazzolo | 1966 | 1:2.5 million | Italy | Mm of eroded soil | Sedimentation measures |
| Soil erosion risk (quantitative evaluation) | Soil erosion hazard factors (5 classes) | Bergsma | 1981 | 1:1 million | Merida province (Spain) | Susceptibility: | |
| | | | | | | Climate aggressivity | Rainfall data |
| | | | | | | Soil profile and lithology | Detailed soil survey |
| | | | | | | Slope | Topography |
| | | | | | | Presence of erosion | Survey and aerial photographs |
| | | | | | | Hazard as above and: | |
| | | | | | | Vegetation | Vegetation map |
| | | | | | | Cultural | Aerial photographs |

### 1.2.2.2. Soil erosion risk

The situation relating to the assessment of soil erosion risk is broadly similar. As the data in Table 1.3 indicate, a range of maps has been produced for the Mediterranean region. These maps, however, vary greatly in scale and methodology, and between them cover only a part of the area under consideration. Many of the previous studies, for example, have been concerned not with assessing the risk of soil erosion, but with mapping the present extent. Amongst these, the surveys by Gazzolo and Bassi (1966) of erosion by water in Italy, and lcona (1 988) in Spain are worthy of particular note, in that they each cover a wide geographic area. Nevertheless, as Table 1.3 shows, these are not compatible either in terms of their scale or assessment procedure: whilst the study by Icona employed modelling techniques based on a variety of physical parameters, the survey by Gazzolo and Bassi (1966) used measurements of fluvial sediment loads.

Assessments of soil erosion risk show the same variety. The survey of France being undertaken by Cadeville-Levy (in press), for example, is essentially a geomorphological survey producing maps showing the main areas of erosion risk, at a scale of 1:2.5 million. The study by Madueño (1987), in contrast, was based on the universal soil loss equation (USLE) of Wischmeier and Smith (1965); that by Quirantes et al. (1987) is concerned specifically with the risk of wind erosion.

lt is apparent, therefore, that existing maps of soil erosion are far from adequate for environmental policy purposes in the European Community. The maps which are available differ in terms of the types of erosion to which they refer, the parameters on which they are based, the assessment models, the scales of representation and the erosion classes used. Even in total, they also cover only a small part of the territory of southern Community Member States. Again, therefore, the Agricultural Directorate of the European Commission, in establishing the 1984-88 coordinated agricultural research programme, has initiated a range of detailed projects on soil erosion and land management and organized several international seminars. As will be indicated below, members of this research group also collaborated closely in the development of the CORINE project on soil erosion risk.

### 1.2.3. Aims of the project

From what has been said, it is clear that, prior to the current project, inadequate information existed on both land quality and soil erosion risk appropriate to underpin environmental policy in the European Community. Given the increasing threat to land resources, and especially the growing problem of soil erosion in Mediterranean regions, an urgent need thus exists to provide information which can help to target policy actions to the areas of greatest need. In accordance with the Decision of the Council of Ministers setting up the CORINE programme, the aims of this project were thus to contribute to this objective by:

(i) collecting and collating data referring to land quality and soil erosion risk in southern Community Member States;

(ii) integrating these data into a consistent and coherent information system which will allow the analysis and mapping of land quality and soil erosion risk at a scale suitable for policy applications;

(iii) developing methods for the assessment of land quality and soil erosion risk which can be used with these data;

(iv) producing preliminary maps of land quality and soil erosion risk, on the basis of these methods, which can both illustrate the potential of the information system, and provide information for immediate policy use;

(v) evaluating the methods used, and the results obtained, to indicate future research needs and ways in which the current work may be developed, extended and improved.

# 2. Working procedures

# 2.1. Organization

The work on the CORINE project on land quality and soil erosion risk was undertaken by a project team, under the leadership of Professor A.Giordano. The project team comprised experts from each of the Member States involved, selected for their experience in research in land resources and soil erosion and, especially, for their previous involvement in compilation of the 1:1 million soil map of the European Communities (Figure 2.1). Each of these members of the project team was responsible for contributing to methodological development; collection and collation of data for their own national or thematic area; checking, correction and interpretation of results; and reporting of all work carried out.

Where appropriate, members of the project team were aided by other consultants, advisers and technical assistants.

Data processing - including digitizing, integration, analysis and plotting - was carried out initially at Birkbeck College, London and subsequently at CORINE headquarters in the offices of DGXI in Brussels. Close links were also established with other services in the Commission (agriculture, research) which participated in the progress of the work.

Full reference to the experts involved is provided in the list of contributors

## 2.2. Timetable and structure of work

The general timetable of the work is shown in Figure 2.2. As this indicates, the project was initiated in early 1985, soon after adoption of the CORINE programme. Three main phases of work can be distinguished:

### 2.2.1.Methodological development

### 2.2.2. Data collection and pretreatment

### 2.2.3. Data analysis

Figure 2.1 Organizational structure of the soil erosion/land quality project

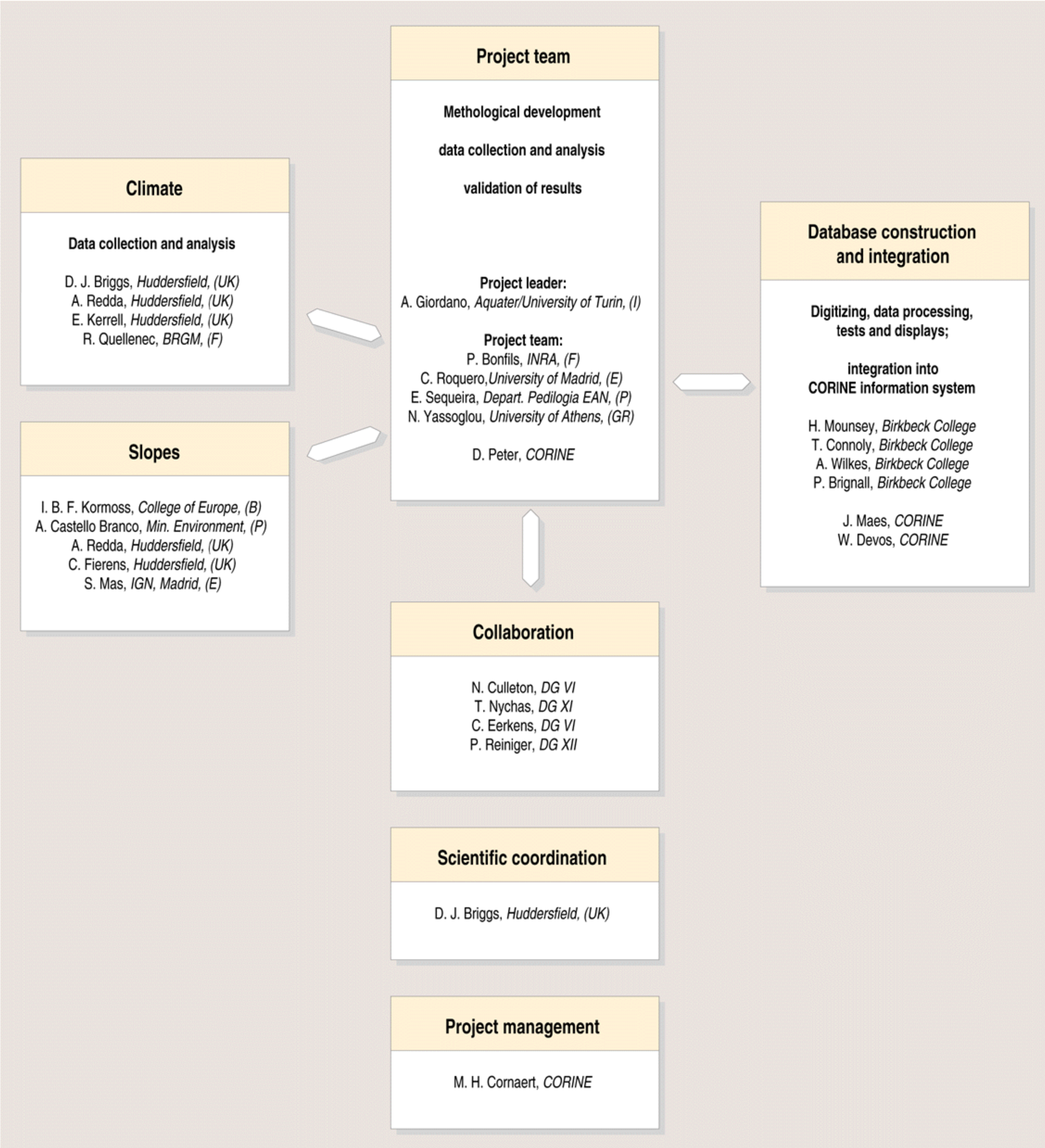
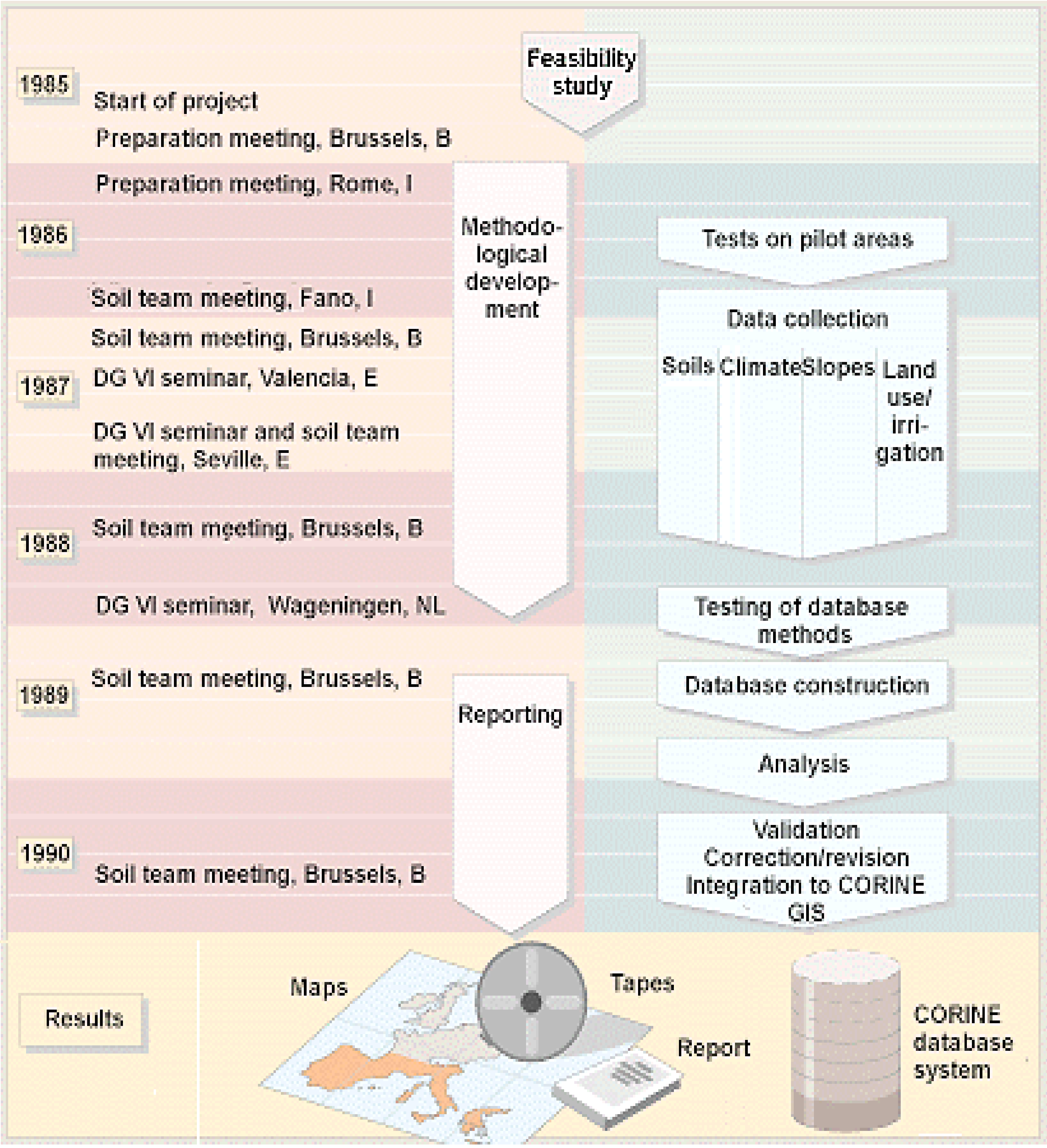


Fig 2.2 - Timetable of work



## 2.2.1.Methodological development

The assessment methods, to he used to derive information on land quality and soil erosion risk, were developed via an iterative process of discussion, research and testing. Initially, a general framework was defined by the project leader and scientific coordinator, taking account of known constraints of data availability and the need for consistency with other CORINE data sets. This set the geographic limits of the project as the area south of 46°N, and the scale of analysis as 1:1 million. lt also specified the main outputs to be produced.

Following a series of bilateral discussions with individual experts, this framework was presented to the project team, and invited experts, at a workshop in Fano in September 1986. At this meeting, a provisional methodology was devised and - in subsequent months - tested in a series of pilot studies and in the CORINE transfrontier project in Algarve and Andalusia (Figure 2.3). As a result of these pilot studies, and further workshops (Figure 2.2), the methodology was
then revised and refined, and a definitive manual produced (Giordano, 1987).

The initial phase of methodological development took around 18 months, by which time data collection had also started. Inevitably in a project such as this, however, each new phase of work generates new awareness, and the overall performance of the methodology could only be assessed as the full results emerged from across the study area. As a consequence, the details of the method had to be repeatedly re-examined and adjusted throughout the course of the work, and it was not until late in the project that a stable procedure was agreed (a third updated version of the manual was produced in January 1988)

Even this methodology, it should be stressed, is regarded only as a 'first approximation'. Further modifications and improvements will undoubtedly be possible given additional research, and a series of recommendations are provided in Chapter 7 of this report.

## 2.2.2. Data collection and pretreatment

The second phase of work involved the collection and pretreatment of the input data required for the assessment procedures. As Figure 2.2 indicates, this started in early 1987 and continued until early 1989. This was in many ways the most complex phase of work, for it involved considerable effort both to locate suitable data sources, and to ensure that
the data were reliable, compatible and comprehensive, and were extracted and treated in a consistent way.

At the same time, it was essential that all data supplied for input to the CORINE database and subsequent analysis were in the correct format. Since the data were being obtained from a wide variety of regional, national and international sources - including published and unpublished maps and reports, existing databases, new data collection exercises, and the work of other CORINE projects - this was a formidable task.

lt was achieved through a number of means, including:

(i) regular meetings of the project team;

(i i) frequent local tests and checks of the methodology and adjustments to the parameters used;

(iii) where necessary (e.g. to ensure cross-border consistency) bilateral meetings, discussions and field visits by the relevant members of the project team;

(iv) the provision of standard base maps, on which all mapped data could be compiled;

(v) the provision of clear data formats and, where appropriate, preprogrammed input procedures for reporting and encoding of data;

(vi) passing of all data through a central group (under the supervision of the CORINE scientific coordinator) so that their consistency could be checked and, where necessary, the data could be reformatted ready for input to the CORINE database;

(vii) further checks of the data as they were input to the CORINE database and during and following analysis.

The importance of all these measures can hardly be overemphasized, for errors in data input to the computer system can cost many weeks of wasted time during subsequent analysis.

Despite these rigorous procedures, however, a number of errors and inconsistencies remained undetected until the final stages of analysis. This arose, it seems, largely through the failure of individual members of the project team to follow precisely the agreed methodology, and the difficulties thereafter of identifying errors in the raw data. lt is often only at the stage of analysis and actual use that the problems become apparent.

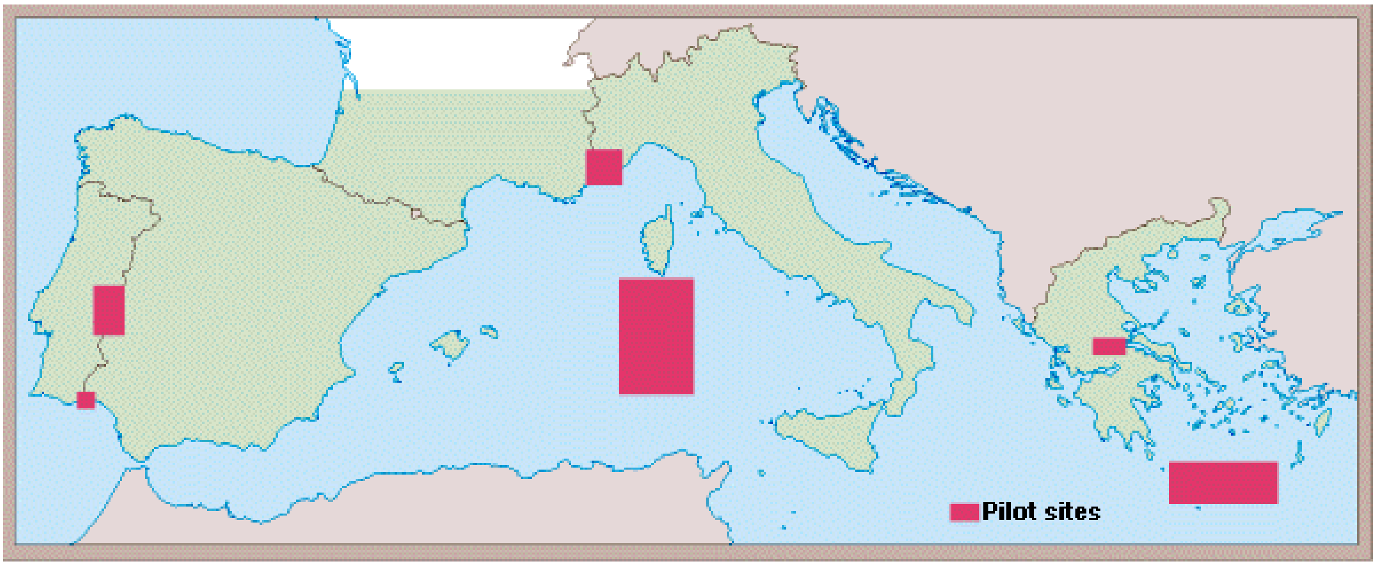
Such mistakes are costly, and they undoubtedly caused delays in the progress of this work. From experience with other, similar projects, however, it appears that the problem is not unusual: it is probably unavoidable. The lesson is that it can only be minimized by even more stringent control and supervision of the work than employed here - including, perhaps, regular on-site inspections of the work, frequent reporting back on the work undertaken and confirmation of the methods used, and repeated restatement of the agreed procedures.

At the same time, as noted above, this phase of the work revealed a number of limitations of the initial methodology. Some of the adjustments which were made created new data needs, and thus necessitated the collection of new data. Inevitably this, too, caused some delay in this stage of the work. lt was also impossible in some cases to proceed to the phase of analysis until all data had been collected, since mapping depended on a full and consistent coverage of the area. Difficulties of data acquisition were thus a further cause of delay.

Whilst data collection was in progress, however, it was also necessary to look ahead to the stage of computer analysis. This was essential on the one hand to identify appropriate formats for data collection and provision. It was vital, on the other hand, to prepare the computer techniques for the analysis phase. For this purpose a further case study was set up covering Sardinia and Crete, in which different analytical procedures were tested and compared.

Prior to analysis a number of data processing tasks had to be performed in order to render the data fully consistent with each other. These comprised the registration to a standard geographic base and the preparation of test plots on which checking was carried out by the appropriate members of the project teams, in collaboration with the project leader and scientific coordinator. Where necessary, the data were then corrected prior to further analysis.

Figure 2.3 -. The project area and location of pilot sites



## 2.2.3. Data analysis

The third phase of the work comprised data analysis, interpretation and validation of the results, and reporting on the project as a whole.

Analysis involved the overlay and aggregation of the various data sets to derive more composite information on land quality and soil erosion risk.

Following analysis, results were plotted and provided again to the project team for interpretation and validation. Given the synthetic nature of the results - and the *de facto* lack of independent information against which to check them - validation was inevitably a largely subjective process. Each member of the project team was nevertheless able to compare the results for areas with which they were familiar with the reality, and on this basis judge the quality of the information.

Reporting was achieved through the submission of a series of national reports, each providing details of data sources, any manipulation of the data, an evaluation of the results, and recommendations for future revision and improvement of the methodology. This document represents a synthesis of these national reports.

# 3. Methodology

## 3.1. General principles

In common with all other CORINE projects, the assessment of soil erosion risk and land quality was required to follow the general principles laid down in the Council Decision which established the programme. These included:

(i) the need for scientific rigour in the methods used;

(ii) the need for transparency in the methodology;

(iii) the need to provide results appropriate for policy applications;

(iv) the need to be consistent across the Community;

(v) the need to use existing data as far as possible;

(vi) the request that work be concentrated on areas where Community structural Funds were involved.

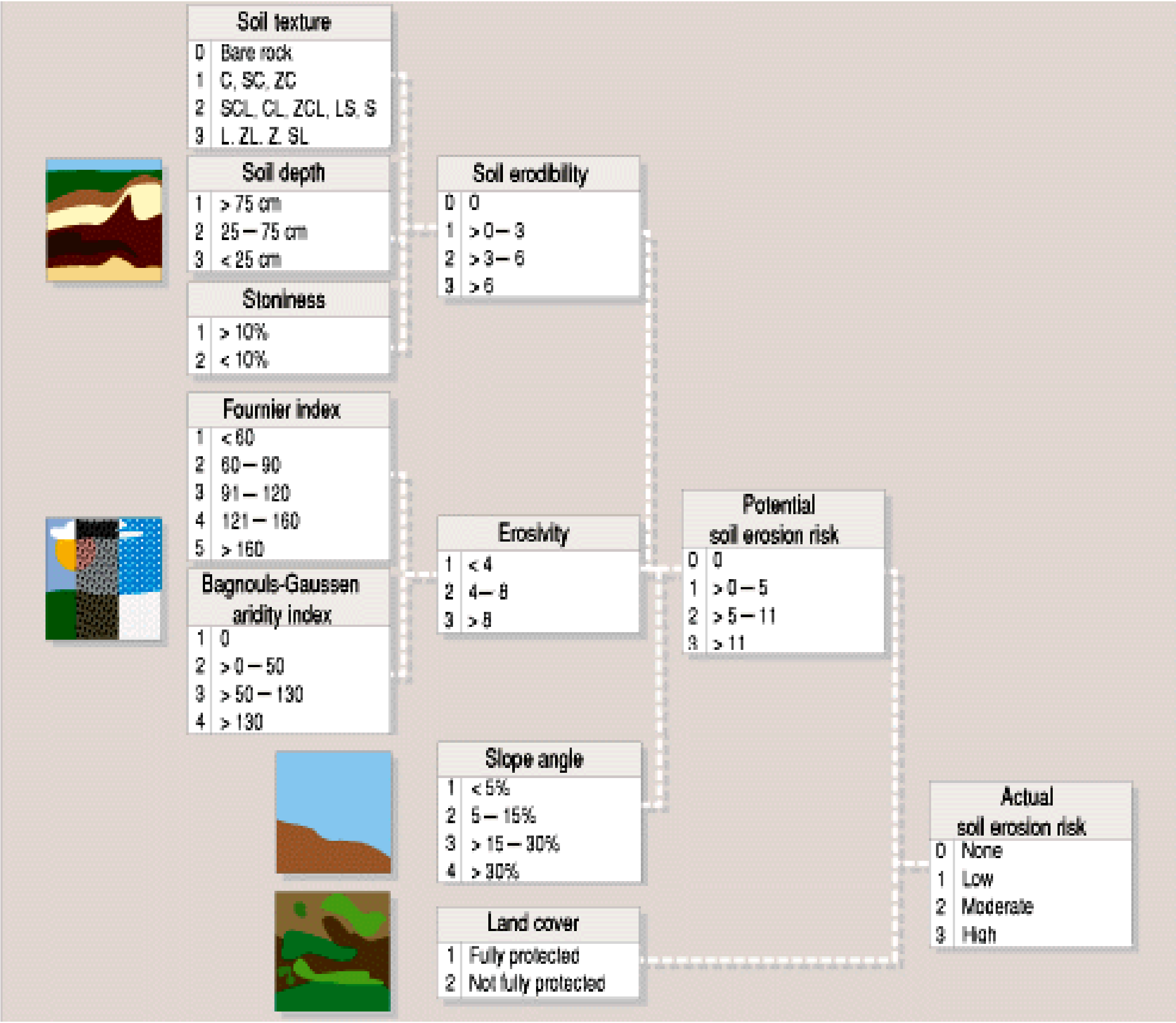
These principles have acted to guide the work, but they have also imposed a number of operational constraints and generated the necessity for a number of compromises. Similar compromises have also been necessary because of the limitations of time and budget.

Many previous investigations of both soil erosion and land quality have, for example, been carried out in the European Community. The methods used, and the results they have produced, are however far from comparable, whilst their geographic coverage is anything but complete. Consequently, they cannot provide the comprehensive and consistent information required of this project, and there has been no choice but to undertake a considerable amount of basic data collection and analysis.

Fortunately, the methodological development on which to base such analyses has, to a great extent, already been carried out. The universal soil loss equation, developed in the USA by Wischmeier and his colleagues (Wischmeier et al., 1971) and the FAO framework for land evaluation (FAO, 1976) each provide a widely accepted starting point for analysis. For various reasons, however - including their geographic bias, their intended scale of analysis, and their data requirements - neither of these could be used in their original form. Instead, the methods had to be adapted and modified to meet the needs and constraints of the current exercise.

At the same time, the availability of basic data in the European Community (and especially in its southern regions) is itself limited. Lack of data - and especially lack of consistent data - has thus limited the approaches which could be followed, and reduced the quality of the results. The geographic extent of the study also represents a major consideration. The area concerned covers the whole of the southern region of the European Community, south of 46°N an area of approximately 1.2 million $km^2$. Clearly, to cope with such a large area, analysis must be carried out at a relatively small scale. On the other hand, the Mediterranean region is by its very nature highly variable and geographically diverse. Soil erosion and land quality both vary at the local scale. If the results are thus to make sense, both scientifically and in terms of policy applications, over-generalization must be avoided. For these reasons, the decision was taken to carry out the analysis at a scale of 1:1 million. This provides a maximum resolution of about 1 km in real space. As such, the level of resolution is clearly low, but given the problems of availability of data is the best that can be achieved, and considering that the exercise is a 'first approximation' can be regarded as acceptable. It is also consistent with a number of other data-sets in the CORINE information system.

Figure 3.1 - Soil erosion assessment methodology



## 3.2. Soil erosion risk: the assessment model

## 3.2.1. Theoretical basis

As has been noted, assessments of soil erosion risk was based upon the principles and parameters defined in the universal soil loss equation (USLE). This model was developed in the USA by Wischmeier and colleagues (Wischmeier et al., 1971) as a means of computing field-scale assessments of soil loss by rainfall from agricultural land. More specifically, its purpose was to provide a basis for advising farmers on soil conservation measures. As such, the model was designed to be used at a specific (i.e. local) scale, and in an area where erosion was a product essentially of Hortonian overland flow (i.e. runoff occurred as a result of high-intensity storms in which precipitation rates exceeded the infiltration capacity of the soil).

On this basis, the USLE defines soil loss as the product of five main factors, as follows:

(i) soil erodibility (k), itself a function of soil properties such as texture, organic matter content, permeability and bulk density;

(ii) rainfall erosivity (r), computed in the USLE as the total rainfall kinetic energy of a given event multiplied by the kinetic energy of the maximum 30-minute storm;

(iii) slope conditions (sl), a product of the interaction of both slope angle and slope length;

(iv) management practices (p), including methods of cultivation, soil conservation practices, etc.;

(v) vegetation cover (v), taking account of both vegetation density and structure.

Based on many years of empirical observation, field trials and laboratory experimentation, the USLE defines strict procedures by which each of these factors may be quantitatively assessed. The results are then entered into the following equation to calculate soil loss (E):

**E = k . r . sl . p . v**

In this form, the USLE has been widely and successfully applied in the USA for many years. In so far as it specifies the basic factors involved in soil erosion by rainfall, it can also clearly provide the foundation for this analysis of soil erosion risk in southern Europe. For a number of reasons, however, the model could not be used in its original form. Amongst others, these included:

(i) the circumstances that the model was developed specifically for USA conditions, and Wischmeier (1976) himself, for example, has warned against its use elsewhere without appropriate modification;

(ii) the fact that it was developed explicitly for use at the local scale, as a basis for practical farm advice, as opposed to the more general regional scale and broader policy applications required here;

(iii) the stringent data demands of the original method, which would not be achievable for much of the southern region of the European Community.

Consequently, the project team endeavoured to modify and adapt the model to meet the requirements of this project. This was no easy task. Any simplification of the model was dangerous, in that it might undermine its integrity and reduce the quality of its performance. Moreover, without careful testing and calibration, the results of any changes introduced could not be assessed. Proposed adaptations therefore had to be evaluated both by studies of previous literature and by conducting pilot studies within the study area. Even so, it should be stressed that the soil erosion model which was thereby developed is seen solely as a first approximation. Further refinement will undoubtedly be feasible
as data availability improves and experience with using this preliminary model is acquired.

## 3.2.2. The assessment procedure

An outline of the soil erosion model is shown in Figure 3.1. As can be seen, assessments are carried out on a threepoint scale ranging from 1 (low) to 3 (high), with an additional class of 0 (no erosion) for areas in which no soil exists (e.g. bare rock, urban land). As such, the model clearly represents a considerable simplification of the USLE, but it is felt that, at the scale and with the data available, this is all that is justifiable. Nevertheless, the results provide sufficient discrimination to meet general policy needs. In particular, they allow the definition of areas of high erosion risk, where active measures to control soil erosion may be needed, and of areas of low risk where agricultural practices probably present no threat.

Assessment is carried out in two steps. First, potential soil erosion risk is calculated by aggregating the indices on soil erodibility, rain erosivity and slope angle. This is taken to indicate the inherent susceptibility of the land to erosion, irrespective of existing land use. lt thus provides a worst possible case.

Actual soil erosion risk refers to the estimated present risk, taking account of current land use practice. This is calculated by also including the vegetation cover index, to modify the estimated potential erosion risk.

lt is also apparent that a third level of analysis is possible by combining these two sets of results. This indicates those areas which are inherently susceptible to erosion, but which are presently protected by vegetation. In policy terms, this is likely to be of particular significance since it highlights areas which may be adversely affected by policy-induced land use changes (e.g. deforestation or agricultural intensification).

The model thus involves the computation of four separate indices, which are then combined to given an assessment of erosion risk:

(i) soil erodibility (defined on the basis of soil texture, depth, stoniness and other modifying properties);

(ii) erosivity (calculated from the Fournier index and Bagnouls-Gaussen aridity index);

(iii) topography; and

(iv) vegetation cover.

The way in which these are classified and combined is outlined in Figure 3.1. Further details are given below.

## 3.2.2.1. Soil erodibility

Soil erodibility refers to the susceptibility of the soil to erosion. At a general level, this depends primarily on the structural stability of the soil (and hence its resistance to particle detachment by rainsplash or runoff) and on its ability to absorb rainfall (i.e. its infiltration capacity, permeability and transmissivity). These properties, in turn, depend on a number of more basic attributes, including soil texture, organic matter content, carbonate content, salinity and pH. Stoniness, also, may be significant, though its effect varies according to circumstances: a surface cover of stones may protect the soil from rainsplash but, once runoff is initiated, the stones may cause turbulence and thereby encourage rilling. Similarly, soil depth is important. Deep soils typically have a higher water holding capacity, and thus are able to absorb larger rainfall amounts before overland flow is generated.

Moreover, erosion of deep soils is considered to be less problematic because of their greater tolerance to erosion. On this basis, soil erodibility is calculated as shown in Figure 3.1.
Three main attributes are involved - soil texture, soil depth and stoniness - from which a quantitative assessment of erodibility is made. This may then be adjusted by up to 1 class value by reference to other (unquantified) modifying factors. The classification procedure and means of aggregation is described below.

Soil texture is classified according to the USDA textural classification (Figure 3.2) on the basis of the following size grades:

Clay (C) particles < 0.002 mm diameter;
Silt (Z) particles 0.002 to 0.05 mm diameter;
Sand (S) particles 0.05 to 2.00 mm diameter.

The soil texture class is derived as follows:

| Soil texture | Class | Description | Texture |
|---|---|---|---|
| | 1 | Slightly erodible | C, sc, zc |
| | 2 | Moderately erodible | SCL, CL, ZCL, LS, S |
| | 3 | Highly erodible | L, ZL, Z, SL |

Soil depth is defined as the depth (in mm) from the soil surface to the base of the soil profile (i.e. the top of the regolith or unweathered parent material). It is classified as follows:

| Soil depth | Class | Description | Depth (mm) |
|---|---|---|---|
| | I | Slightly erodible | > 750 |
| | 2 | Moderately erodible | 250 to 750 |
| | 3 | Highly erodible | < 250 |

Stoniness refers to the percentage surface cover of stones (> 20 mm) and is classified as follows:

| Stoniness | Class | Description | Percentage cover |
|---|---|---|---|
| | 1 | Fully protected | > 10 |
| | 2 | Not fully protected | <- 10 |

Soil erodibility is calculated as the product of these three attributes, as follows:

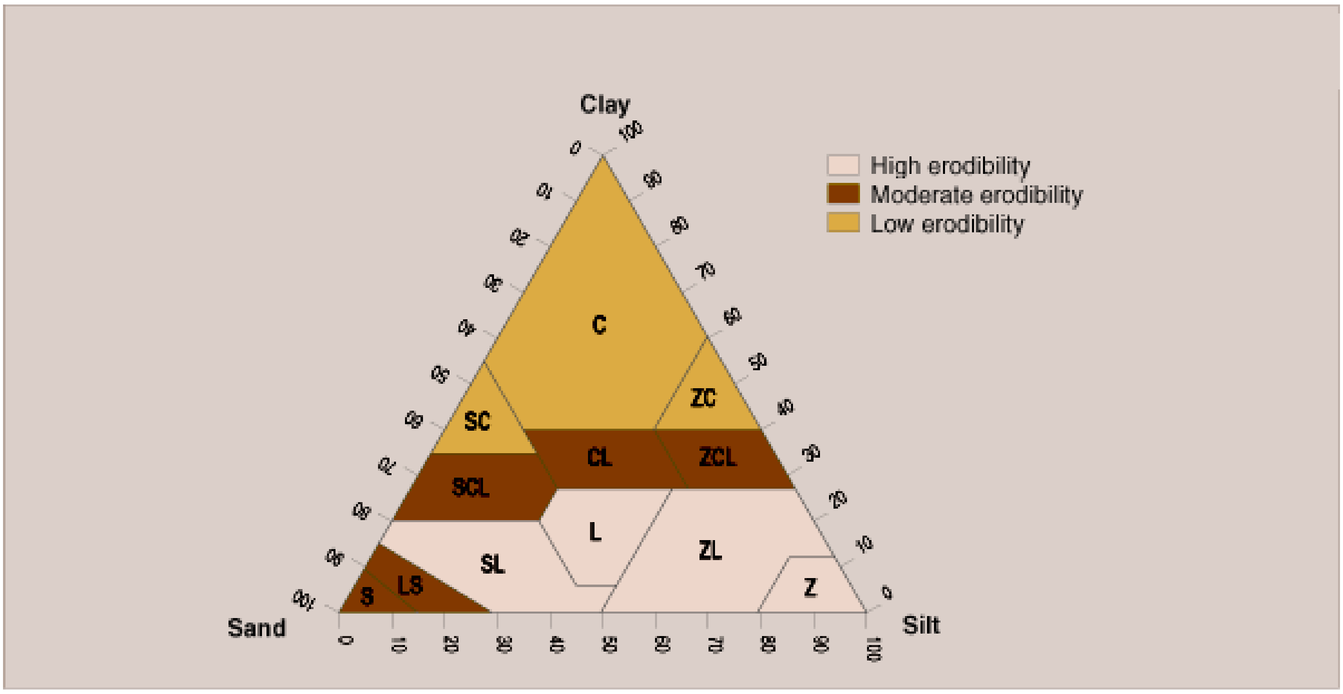
**Soli erodibility index = texture class x depth class x stoniness class**

The soil erodibility index is then scaled as follows:

| Soil erodibility | Index | Description | Range |
|---|---|---|---|
| | I | Low | > 0 to 3 |
| | 2 | Moderate | > 3 to 6 |
| | 3 | High | > 6 |

This index can be adjusted by up to one class on the basis of other modifying factors (e.g. organic matter, parent material, presence of adjacent bedrock outcrops). All such modifications are annotated in the source document. A soil erodibility index of 0 (no erosion) is assigned to areas with no soil cover (e.g. bare rock, urban land, water).

Figure 3.2 - Textural classes for soil erodibility assessment



## 3.2.2.2. Erosivity

Rainfall erosivity depends primarily on rainfall intensity and amount. As noted earlier, in the case of the USLE, this is assessed in terms of the kinetic energy of the total rainfall kinetic energy of a given event multiplied by the maximum 30-minute rainfall, these values being summed for all storms over the assessment period.

For the reasons that have been mentioned previously - that is, the differences in scale, environmental conditions and data availability - this approach was not considered appropriate here. Instead, the decision was taken to use two more general indices as a basis for calculating erosivity: a modified version of the Fournier index, and the BagnoulsGaussen aridity index.

The modified Fournier index is defined as:

$$FI = \sum_{i=1}^{12} \frac{P_i^2}{\bar{P}}$$

where: P, is the precipitation total in month i, and P is the mean annual precipitation total.

As such, it provides a measure of rainfall variability, large values of FI relating to high variability, low values characterizing sites with an evenly distributed rainfall (Figure 3.3). The original Fournier index was devised specifically to provide a measure of erosivity which could be applied at a regional scale (Fournier, 1960). Since then, the index - and derivatives from it - have been widely applied, most especially in analyses of erosion from river basins. These studies have shown that the index correlates broadly with both the USLE erosivity index and with rates of erosion at a basin scale.

The Fournier index is classified as follows:

| Variability | Class | Description | Range |
|---|---|---|---|
| | 1 | Very low | < 60 |
| | 2 | Low | 60 to 90 |
| | 3 | Moderate | > 90 to 120 |
| | 4 | High | > 120 to 160 |
| | *5* | Very high | > 160 |

Nevertheless, although the Fournier index gives an acceptable measure of rainfall variability, it does not take into account the general aridity of the climate, and hence the likelihood of short-period intense storms during otherwise dry seasons. Nor does it consider the moisture stress which may occur, reducing vegetation cover and thereby increasing the opportunity for soil erosion.

Consequently, to strengthen the assessment of erosivity, a second climatic index was included: the Bagnouls-Gaussen aridity index (BGI). This is defined as:

$$BGI = \sum_{i=1}^{12} (2t_i - P_i) \cdot k_i$$

where: ti is the mean temperature for month i;
Pi is the total precipitation for month i; and
k, represents the proportion of the month during which 2t, - Pi > 0
The method for calculating BGI is illustrated in Figure 3.4.
The Bagnouls-Gaussen index is classified as follows:

| Aridity | Class | Description | Range |
|---|---|---|---|
| | 1 | Humid | 0 |
| | 2 | Moist | > O to 50 |
| | 3 | Dry | > 50 to 130 |
| | 4 | Very dry | > 130 |

These two climatic indices are classified and combined to give the erosivity index as follows:

**Erosivity index = variability class x aridity class**

| Erosivity Index | Description | Range |
|---|---|---|
| 1 | Low | < 4 |
| 2 | Moderate | 4 to 8 |
| 3 | High | > 8 |

Figure 3.3 - Examples of the Fournier index (Fi) for selected climatic stations

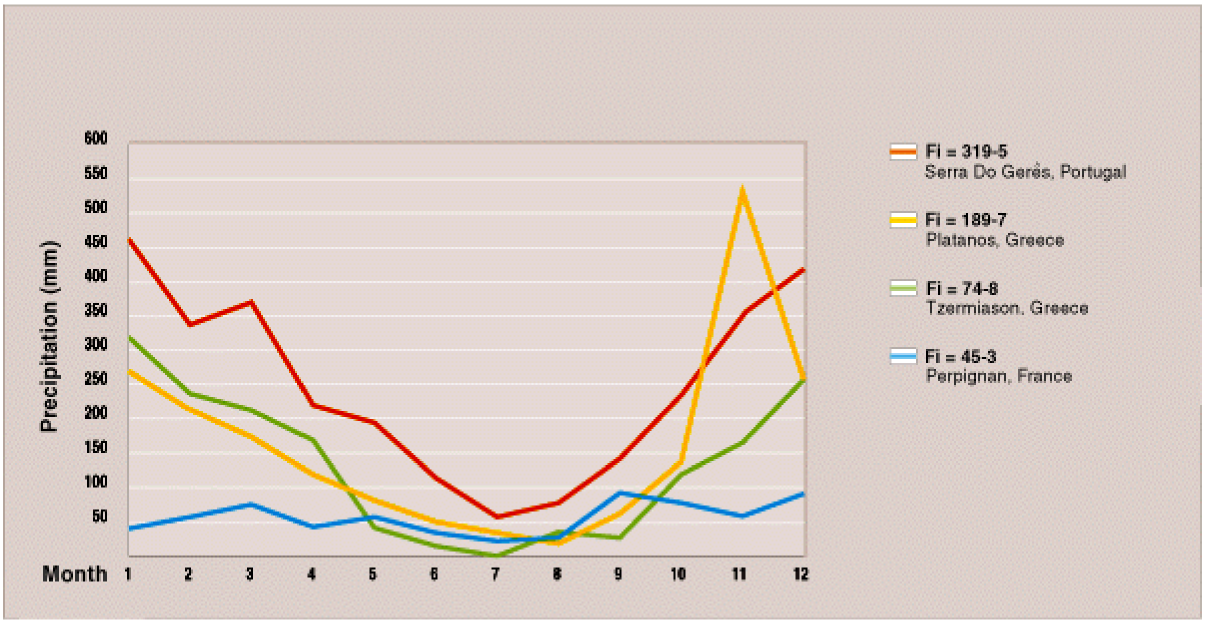
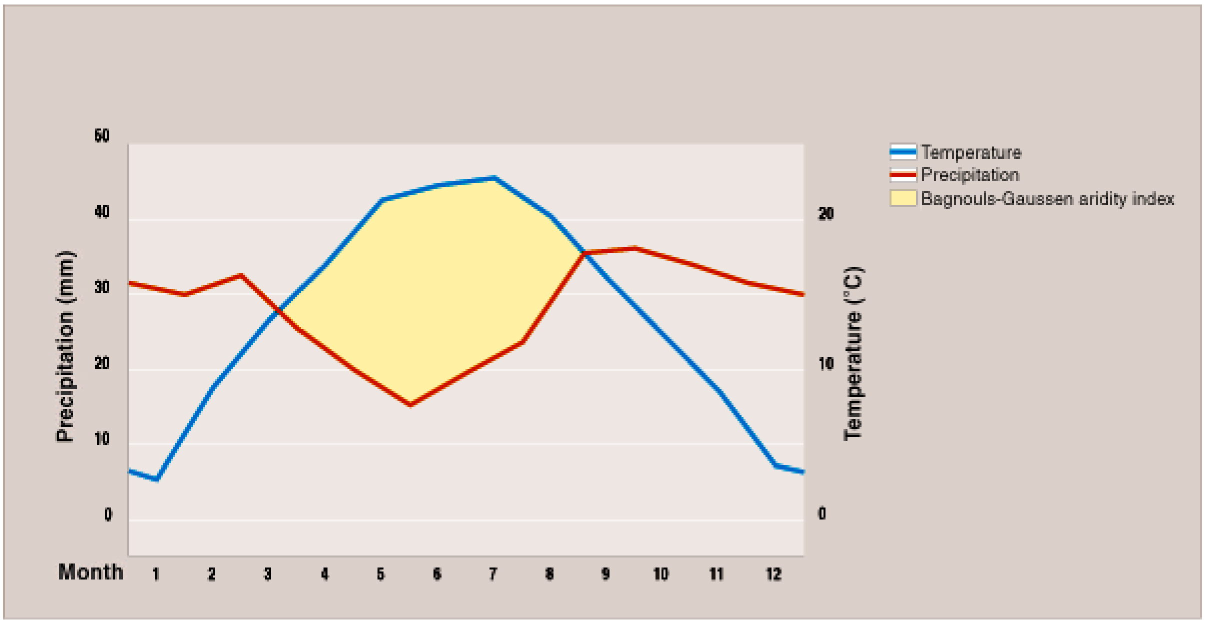



Figure 3.4 - Calculation of the Bagnouls-Gaussen aridity index



## 3.2.2.3. Topography

Topography undoubtedly provides one of the most important determinants of soil erosion. Typically, erosion only becomes acute when slope angle exceeds a critical steepness, and then increases logarithmically thereafter. Runoff, and erosion, also tend to increase with increasing slope length (Figure 3.5). The effect of topography also often operates at an essentially local level, erosion being initiated at specific locations on the slope, or in association with minor topographic variations. For this reason - perhaps more than for either soil or climate - data on topography need to be relatively detailed.

In the case of the USLE, this is achieved by the use of information on both slope angle and length derived from field surveys or from detailed topographic maps. In the case of slope length, account is also taken of barriers to overland flow, such as walls, ditches or terraces. In the current study, such detail is clearly impracticable, and a more general approach had to be adopted.

Accordingly, the topographic factor in the CORINE erosion model is defined solely in terms of the average maximum regional slope angle (%). This is measured for each kilometre grid square, from topographic maps, digital terrain models, satellite imagery or other sources.

Slope angle, as thus measured, is then classified as follows:

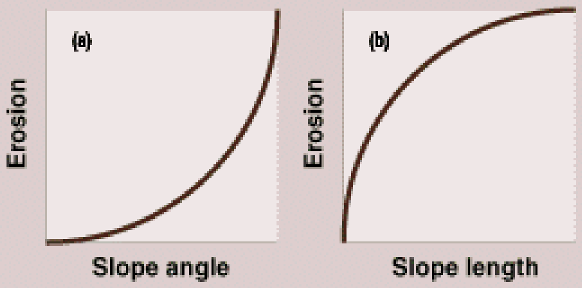
| Slope | Index | Description | Slope angle |
|---|---|---|---|
| | 1 | Very gentle to flat | < *5* |
| | 2 | Gentle | 5 to 15 |
| | 3 | Steep | > 15 to 30 |
| | 4 | Very steep | > 30 |

## 3.2.2.4.Vegetation cover

In practical terms, vegetation cover presents possibly the most crucial clement in the slope erosion model, since it is the one factor that can readily be altered, and therefore provides the main opportunity for erosion control. It is also widely established that quite minor adjustments in vegetation cover may significantly affect rates of erosion. Ideally, therefore, detailed and reliable information on land use and vegetation cover needs to be available as an input to the model. At the scale of analysis being used here, unfortunately, this is not yet feasible. The maps of land use and vegetation cover which are available are normally highly generalized, inconsistent from one area to another, and often out of date. Remote sensing, whilst providing an important source of information for the future, has not yet been applied sufficiently to provide the data required (although the CORINE land cover project has been able to supply data for Portugal, and will in the future obviously be an ideal data source).

Instead, and solely as an interim measure, a simple binary classification of vegetation cover has had to be used:

| Vegetation | Index | Description | Vegetation type |
|---|---|---|---|
| | I | Fully protected | Forest, permanent pasture and dense scrub |
| | 2 | Not fully protected | Cultivated or bare land |




*Source: Finlayson and Statham, 1980.*

### 3.2.2.5. Potential soil erosion risk

Potential soil erosion risk is defined as the inherent susceptibility of the soil to rainfall erosion, irrespective of vegetation cover or land use. As noted previously, this represents the worst possible case. lt is derived as follows:

**Potential soil erosion risk index = soil erodibility index x erosivity index x slope index**

The potential soil erosion risk index is classified as follows:

| Potential soil erosion risk | Index | Description | Range |
|---|---|---|---|
| | 0 | None | 0 |
| | 1 | Low | > Oto5 |
| | 2 | Moderate | > 5 toll |
| | 3 | High | > 11 |

### 3.2.2.6. Actual soil erosion risk

The actual soil erosion risk index relates to the current risk of erosion under present vegetation and land use conditions. It is derived by modifying the estimated potential soil erosion risk index according to the vegetation cover, as follows:

| Potential soil erosion risk index | | None | Low | Moderate | High |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Vegetation index | 1 | 0 | 1 | 1 | 2 |
| | 2 | 0 | 1 | 2 | 3 |

## 3.3.Land quality: the assessment model

### 3.3.1. Theoretical basis

### 3.3.2. The assessment procedure

### 3.3.1. Theoretical basis

Land evaluation means many things to many people. On the one hand, it refers to the specific suitability of land for particular agricultural crops and cropping systems (e.g. rice, potatoes, dry-land wheat) or non-agricultural activity (e.g. golf courses, campsites). As such, evaluation must depend upon a detailed understanding of the environmental requirements for the specified crop or activity, and evaluation methods are likely to vary according to the particular circumstances involved. This approach has already underlain the research on land suitability undertaken by the Directorate-General for Agriculture. On the other hand, land evaluation may also refer to the much broader capability of the land. In this case assessments refer to the overall capacity of the land to support general land uses, such as agriculture, recreation or forestry. It is this latter approach which is considered more appropriate here, since the aim is to identify the general quality of the land resource.

As has been noted, the FAO framework for land evaluation (FAO, 1976) provides a well-tested and widely accepted basis for assessing land quality. This defines the broad structure for assessment and identifies the main factors that should be considered. It distinguishes between evaluation of the physical resource base - the inherent quality of the land resources - and that of the wider management system. Yet it stresses, also, the intimate link between the two and points out that any land evaluation should be conducted within a specified socioeconomic context.

In terms of the physical resource base, the framework indicates three main factors which determine land quality:

(i) soil conditions, especially soil moisture capacity, nutrient status;
(ii) climatic conditions, including the length of the growing season, effective precipitation and climatic hazards (e.g frost, drought);

(iii) topographic conditions, especially slope angle.

It does not, however, define a particular assessment procedure, by which these factors should be classified or aggregated into a land quality index, but leaves this to be developed for each application, according to the specific circumstances and requirements. In assessing land quality in southern Community countries, therefore, the project team needed to translate the broad structure of the framework into an operational methodology.

As with the development of the soil erosion risk procedure, this was no easy task. Limitations of data, the conflicting demands for both precision and generality, and the diversity of conditions in southern Europe all created major conceptual and practical difficulties. Lack of independent evaluations of land quality against which to calibrate assessments also meant that it was difficult to validate the models which were proposed. A considerable period of model development, testing and review was therefore necessary before the project team was able to devise a procedure which was considered satisfactory.

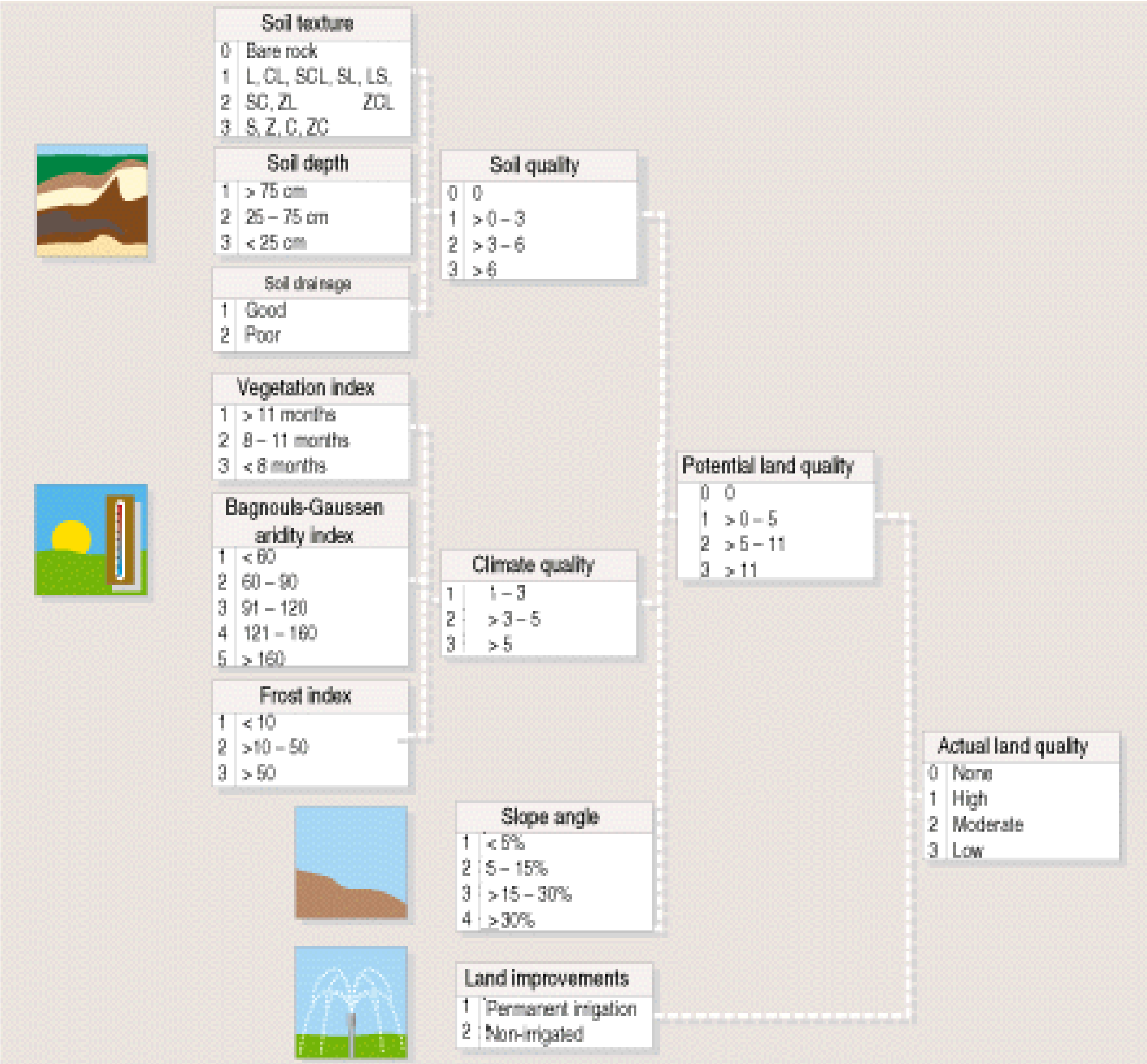
## 3.3.2. The assessment procedure

The model which was developed by the project team is shown in Figure 3.6. Like the soil erosion risk model, it defines land quality on a three-point scale, ranging from 1 (high quality) to 3 (low quality), with an additional class (0) for areas with no inherent quality (e.g. urban areas). Again, assessment takes place in two stages. In the first, the potential land quality is calculated on the basis of physical characteristics of the land: soil conditions, climate and slope. This thus provides a measure of the inherent quality of land resources, irrespective of human efforts to improve the land.

This index is then adjusted to allow for improvements such as irrigation, terracing or drainage. The adjusted quality is referred to as actual land quality and represents the current state of land resources taking account of infrastructural factors. In this case, however, the land quality index is not uprated. Instead, this is identified by a suffix to the quality index, indicating the nature of the improvement: 'i' for irrigation, 'd' for drainage and 't' for terracing.

The model thus involves the computation of four basic indices, which are combined in the assessment procedure:
(i) soil quality (assessed on the basis of soil texture, depth, drainage status and other modifying properties);
(ii) climate quality (calculated from the Bagnouls-Gaussen aridity index, the length of the vegetative period and the frost risk);
(iii) topography (indicated by slope angle); and
(iv) infrastructural improvements (the presence of permanent irrigation, drainage or terracing);

Figure 3.6 - Land quality assessment methodology



## 3.3.2.1. Soil quality

Soil quality refers to the inherent ability of the soil to provide a growth medium for plants. In practice, this is likely to be a function of a wide range of different soil properties which individually or in combination affect growth processes such as germination, root elongation and shoot development, tillering, flowering and fruiting. At a general level, however, many of these properties act through their influence on moisture and nutrient supply to the plant. Thus, at the level of analysis employed here, it was felt legitimate to consider only three properties: soil texture, soil depth and soil drainage.

Soil texture is classified according to the USDA textural diagram (Figure 3.7) on the basis of the following size grades:

Clay (C) particles < 0.002 mm diameter;
Silt (Z) particles 0.002 to 0.05 mm diameter;
Sand (S) particles 0.05 to 2.00 mm diameter.

The soil texture class is derived as follows:

| Soiltexture | Class | Description | Texture |
|---|---|---|---|
| I | Good | CL, SCL, L, SL, LS | |
| 2 | Moderate | ZCL, ZL, SC | |
| | 3 | Poor | C, zc, Z, s |

Soil depth is defined as the depth (in mm) of the soil profile (i.e. from the soil surface to the top of the regolith or unweathered parent material). Soil depth is classified as follows:

| Soil depth | Class | Description | Depth (mm) |
|---|---|---|---|
| | 1 | Deep | > 750 |
| 2 | Moderate | 250 to 750 | |
| | 3 | Shallow | < 250 |

Soil drainage status refers to the presence or absence of drainage problems (waterlogging or drainage impedance) in the soil profile.

Soils with poor drainage status generally include hydromorphic and gley soils, such as those situated in enclosed alluvial basins of low-lying coastal plains. Classification is as follows:

| Soil drainage | Class | Description |
|---|---|---|
| | 1 | Soils with no drainage problems |
| | 2 | Soils with drainage problems |

These three soil parameters are combined to produce a preliminary measure of soil quality as follows:

**Soil quality index = texture class x depth class x drainage class**

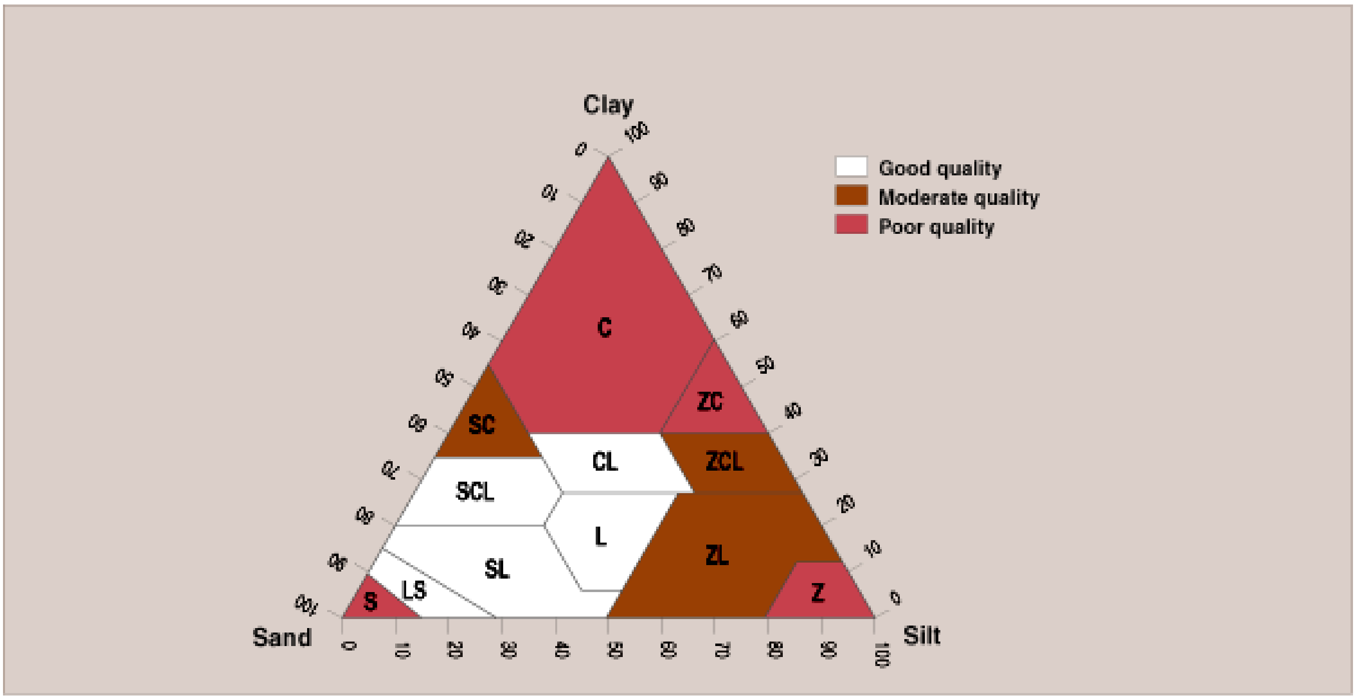
This is then classified according to the following scale:

| Soil quality | Index | Description | Range |
|---|---|---|---|
| | 1 | High quality | < 2.5 |
| | 2 | Moderate quality | 2.5 to 5.5 |
| | 3 | Poor quality | > 5.5 |

Areas with no soil (e.g. urban areas) are assigned an index of 0.

This index may then be adjusted by up to one class on the basis of other, modifying factors such as stoniness, salinity, excessive carbonate content, nutrient status or pH. Definitive criteria for these adjustment factors are not given, but any adjustments must be explained in the supporting documentation.

Figure 3.7 Textural classes for soil quality assessment



## 3.3.2.2. Climate quality

The potential of the climate to support crops or vegetation depends on a wide range of factors which influence growth processes. In the last 10 to 20 years, many attempts have been made to develop models of these processes, and thus provide a basis for predicting crop growth (e.g. France et al., 1981; de Wit and van Keulen, 1987; Stewart and Dwyer, 1986; Williams et al., 1989). Many of these, however, tend to be specific to certain types of crop, and to be highly demanding in terms of their data requirements. Consequently, they are not suitable for the more general assessments needed here.

The main factors which need to be included in the assessment of climate quality are nevertheless clear. They must include a measure of both energy and moisture availability, and of any climate hazards which might inhibit plant growth.

The factor selected to represent energy availability was the length of the growing season. Other measures, such as the accumulated temperature were considered but, in southern areas of the Community at least, these were thought to be inappropriate since much of the energy supplied during summer months is in fact surplus to requirements for plant growth. An index based on accumulated temperature was therefore likely to be potentially misleading.

Instead, the simpler length of the vegetative period was used. This represents the number of months during which the mean monthly temperature exceeds 5°C, as shown in Figure 3.8.

This is classified as follows:

| Vegetative period | Class | Description | Months > 5'C |
|---|---|---|---|
| | 1 | Long | > 11 |
| | 2 | Moderate | 8 to 11 |
| | 3 | Short | < 8 |

Moisture availability represents an important limiting factor in Mediterranean areas, due to the seasonal aridity of the climate.

Probably the most effective measure of moisture availability is provided by an assessment of effective precipitation (i.e. precipitation minus evaporation and runoff). Calculation of effective precipitation, however, demands relatively complex data, and requires some knowledge both of the vegetation and of soil conditions. Thus, the simpler Bagnouls-Gaussen aridity index was used here. This provides a measure of moisture stress in terms of the ratio of the temperature and precipitation, as follows:

where: t, is the mean daily temperature in month i;
Pi is the mean precipitation amount in month i; and
k, is the proportion of month i when the value 2t, - Pi > 0.

The method for calculating BGI is shown in Figure 3.4.

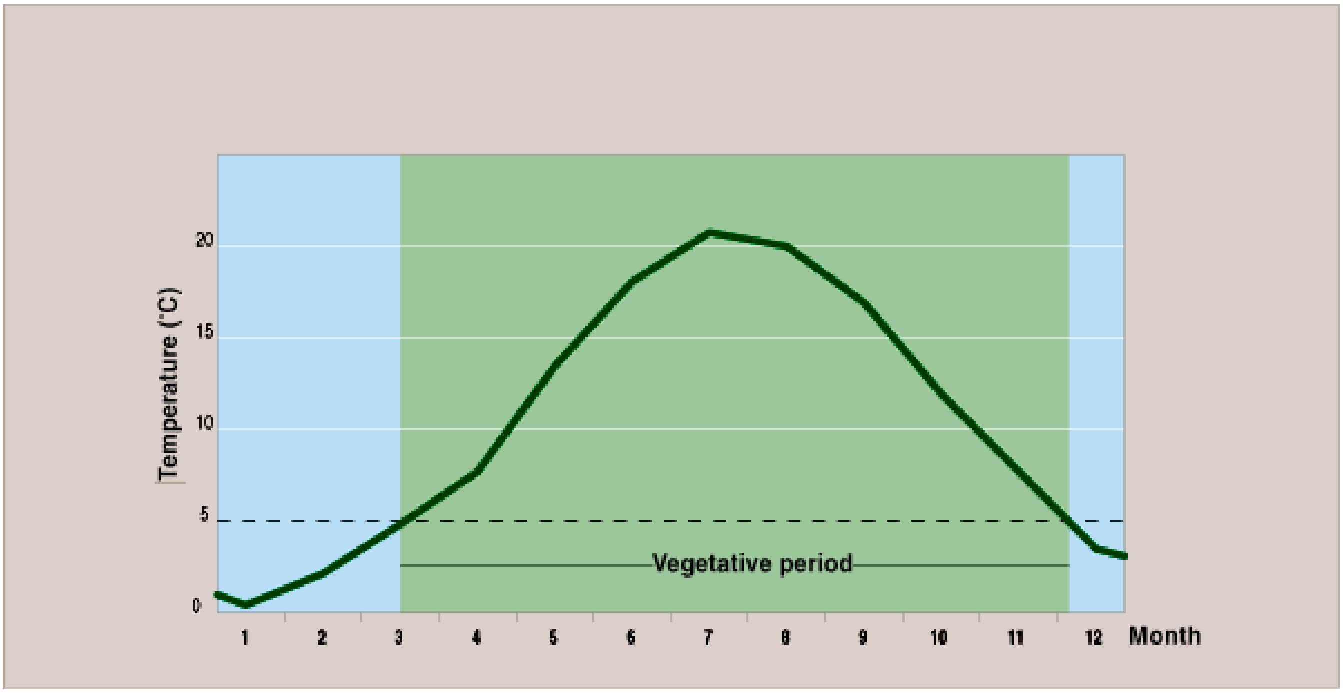
This is classified as follows:

| Aridity | Class | Description | Range |
|---|---|---|---|
| | 1 | Humid | 0 |
| | 2 | Moist | > 0 to 50 |
| | 3 | Dry | > 50 to 130 |
| | 4 | Very dry | > 130 |

As such, the aridity index clearly indicates not only moisture availability but also its inverse, moisture stress. In this sense it also provides a measure of drought hazards.

Other climatic hazards may nevertheless affect vegetation growth, and in southern regions of the Community none is probably more important than frost. Brief, often intense frosts, during active periods of growth may be particularly damaging, especially to sensitive crops such as fruits and vegetables. For this reason, a third climatic parameter is included, which provides an index of frost risk.

Figure 3.8 - Calculation of length of vegetative period




This is based on the average number of days with frost during the vegetative period. Frost events are defined as days when the minimum air temperature falls below O°C, and the vegetative period represents all months when the mean air temperature exceeds 5°C, as above. Because late spring and early autumn frosts are inherently more damaging than those during winter months, however, a weighting is applied to the monthly frost frequency, as follows:

| Weighting | Factor | Months |
|---|---|---|
| | 1.0 | January, December |
| | *1.5* | February, November |
| | 2.0 | March, October |
| | 4.0 | April, September |
| | 6.0 | May, June, July, August |

The frost index (FR) is thus calculated as:

where: F, is the mean number of frost days in month i: and
W, is the weighting factor for month i.

This is classified as follows:

| Frost risk | Class | Description | Weighted frost index |
|---|---|---|---|
| | 1 | Low | -< 10 |
| | 2 | Moderate | > 10 to 50 |
| | 3 | High | *> 50* |

These three variables were then combined to produce an overall index of climatic quality as follows:

**Climate quality index = vegetative period class** x **aridity class** x **frost class**

The climate quality index is then classified as follows:

| Climate quality | Index | Description | Range |
|---|---|---|---|
| | I | High | 0 to 3 |
| | 2 | Moderate | > 3to5 |

| | | |
|---|---|---|
| 3 | Low | > *5* |

### 3.3.2.3. Topography

As with the assessment of soil erosion risk, topography represents a vital component of land quality evaluation. Altitude and aspect, for example, exert important controls on both the regional and local climate, especially through their effect on temperature, precipitation amount and type, wind speed and humidity. More specifically, slope angle affects land quality by its influence on accessibility to the land (particularly by farm machinery), and on runoff and soil stability.

In part, these effects of regional topography are taken into account by the climatic indices. To allow for the direct physiographic influences, however, slope angle was also included. This was assessed, as for soil erosion risk, as the average maximum regional slope angle (%), calculated for each 1-km grid square. Four classes of slope angle are recognized, as follows:

| Slope | Index | Description | Slope angle |
|---|---|---|---|
| | 1 | Very gentle to flat | < *5* |
| | 2 | Gentle | 5 to 15 |
| | 3 | Steep | > 15 to 30 |
| | 4 | Very steep | > 30 |

## 3.3.2.4. Land improvements

Whilst the three basic physical factors - soil, climate and topography - determine the inherent quality of land resources, human activities can in many cases modify these to a significant extent. In particular, land improvements such as terracing and irrigation may upgrade the quality of the land, more or less permanently.

The opportunity to acquire reliable data on improvements of this sort poses severe problems. In time, the CORINE land cover project may provide data; for the moment, however, suitable data are limited. For this reason, no attempt was made to apply a sophisticated or complex analysis of land improvements. Instead, account was taken only of permanent irrigation systems, and a simple classification was used, as follows:

| Improvements | Index | Description |
|---|---|---|
| | 1 | Land with permanent irrigation |
| | 2 | Land without permanent irrigation |

Areas of partially irrigated land were treated as non-irrigated for the purpose of this analysis.

### 3.3.2.5. Potential land quality

Potential land quality refers to the inherent physical quality of the land resources for agriculture, biomass production and vegetation growth. As noted previously, this represents the product of the three basic indices: soil quality, climatic quality and slope:

**Potential land quality index = soil quality index x climatic quality index x slope index**

The potential land quality index is classified as follows:

| Potential land quality | Index | Description | Range |
|---|---|---|---|
| | 0 | None | 0 |
| | 1 | High | > 0 to 5 |
| | 2 | Moderate | > 5 toll |
| | 3 | Low | > 11 |

## 3.3.2.6. Actual land quality

The actual land quality relates to the current quality of the land, under present management conditions. This thus takes account of the existing land improvements. lt is derived by adjusting the potential land quality according to the land improvements index, as follows:

| | | | | | |
|---|---|---|---|---|---|
| Potential land quality index | | None | High | Moderate | Low |
| | | 0 | 1 | 2 | 3 |
| Land improvements index | I | 0 | 1 | 2* | 3* |
| | 2 | 0 | 1 | 2 | 3 |

## 3.4. Data collection and pretreatment

## 3.4.1. Soils

In order to carry out the analyses of both soil erosion risk and land quality, information on a range of soil properties was required:

| | |
|---|---|
| Soiltexture | dominant texture class |
| Soil depth | depth of profile in cm |
| Stonines | percentage surface cover |
| Drainag | presence/absence of drainage problems |
| Organic matter | content (%) |
| pH | pH value |
| Carbonates | content (%) |
| Salinity | presence/absence of salinity problems |

Information on the first four of these was essential for calculation of one or both of the two soil indices (erodibility or quality). The other parameters were all optional.

The main source used to obtain this information was the 1:1 million scale soil map of Europe. This was compiled and published by the European Commission (CEC, 1985) under the agricultural research programme. It provides information on some 350 soil associations, each described in terms of its dominant (major), secondary (minor) and associated soil types. This map was therefore digitized as part of the CORINE project on basic data collection, and integrated into the CORINE geographic base (for a full description of the process, see the CORINE basic data collection report). For all countries except Greece (see below) this was then used as the base map for soil interpretation (Figure 3.9).

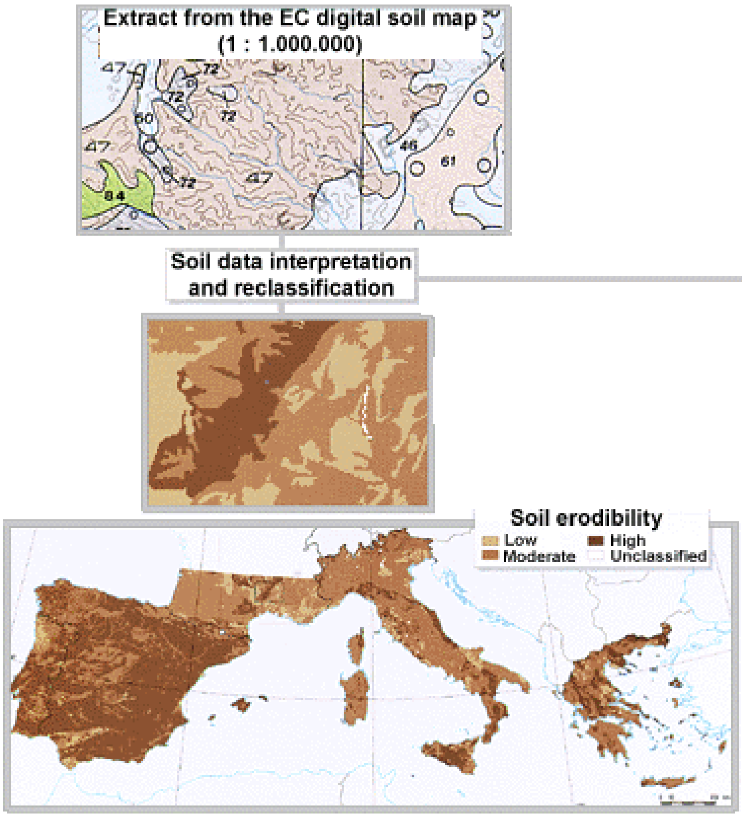
Even so, a number of limitations with this source were encountered. Considerable differences in the quality of the map occur, for example, with soil map units in Greece being as much as 10 times larger than elsewhere - a reflection not of the natural variability of soils but of the differing detail inherent in the sources used. To overcome this problem, and make the data more consistent throughout the study area, the Greek member of the project team (Professor Yassoglou) compiled a revised map of Greece, which was then digitized and appended to the CORINE soils coverage.

In addition, it was apparent that more detailed information was desirable for some soil parameters in certain parts of the study area. For this information, recourse was made to national soil maps. In this respect Portugal, and to a lesser degree France, used some soil units not belonging to the Community soil map or some Community soil map units but not in their original form.

Once all this information was compiled, members of the project team carried out an interpretation of the base soil map. For each country, a table was drawn up giving estimated values of the four primary parameters for each soil class, together - where appropriate - with any adjustment factors. If necessary, new soil classes were also defined, and the boundaries drawn on the base map.

The soil boundaries for the study area were extracted by clipping the coverage at 46°N. Necessary modifications to the soil coverage were carried out (e.g. by editing-in new soil boundaries). The interpretative data were then appended to the soils coverage as an attribute table, linked via the soil code, and redundant boundaries dissolved out.

Figure 3.9 - Derivation of soil erodibility map from the CORINE Community digital soil map




**Example of soil data interpretation**

**Values given to the soil characteristics in the taxonomic units**

| Taxonomic | Texture | Depth | Stoniness |
|---|---|---|---|
| a | SL (3) | 75 (1) | No (2) |
| b | S (2) | 25 & 75 (2) | No (2) |
| c | S (2) | 25 (3) | Yes (1) |
| d | ZC (1) | 25 (3) | No (2) |

**Percentage of taxonomic units in the mapping unit**

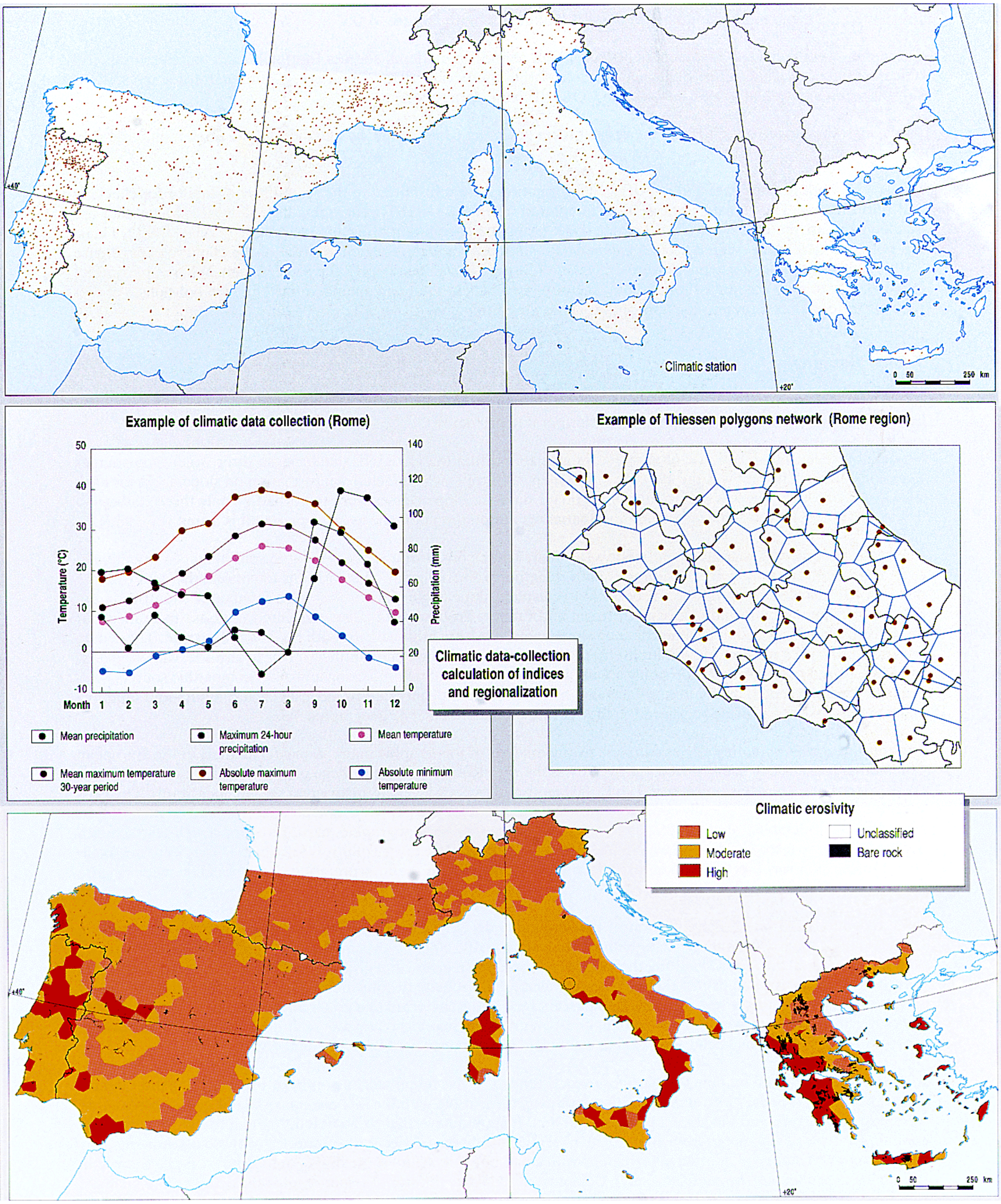
| Mapping unit | Taxonomic units | | | |
|---|---|---|---|---|
| | a | b | c | d |
| | Percentage | | | |
| A | 90 | 5 | 5 | - |

**Values given to the mapping unit**

| Mapping unit | Factor | Mean erodibility | |
|---|---|---|---|
| | | Weighted value of the single factors | Mapping unit |
| A | Texture | $\frac{(90 \times 3) + (5 \times 2) + (5 \times 2)}{100} = 2.90$ | 2.90 |
| | Depth | $\frac{(90 \times 1) + (5 \times 2) + (5 \times 3)}{100} = 1.15$ | x 1.15<br>x 1.95 |
| | Stoniness | $\frac{(90 \times 2) + (5 \times 2) + (5 \times 1)}{100} = 1.95$ | = 6.50<br>rounded to 7 [1] |

[1] Soil erodibility index 3 (high)

Figure 3.10 - Derivation of the climatic erosivity map



## 3.4.2. Climate

Data on climate are required for the assessment of both soil erosion risk and land quality, as follows:

Temperature mean monthly air temperature Precipitation mean monthly precipitation amount
Frost mean monthly number of days with minimum temperature < *O°C*

These data were collected by members of the project team from national sources (normally national meteorological offices). In general, data refer to 30-year norms covering the period 1931-60 or 1941-70, although for some stations shorter records have had to be used (see the CORINE basic data report).

Processing was carried out either by the project team or, in the case of Italy, by members of the project on basic data collection.

In all cases, both the raw data and any derived information were transmitted to the scientific coordinator for checking and reformatting. The climate stations were integrated into the CORINE geographic base and the climate data appended as an attribute data-set, linked by site code. Using the tessellation procedures available in ARC/INFO, Thiessen polygons were then created around each climate station to provide a regionalization of the climatic data (Figure 3.10). Plots of the Thiessen network were drawn and returned to the members of the project team. Where appropriate (e.g. in order to take account of topographic factors), members of the team amended the Thiessen polygons. All corrections were then returned to the appropriate team for editing.

### 3.4.3. Topography

Assessments of both soil erosion risk and land quality require information on slope angle, at a 1-km grid scale. The collection of these data, however, presented considerable problems.

No data on relief (either altitude or slope) were available within the CORINE database, so three other data sources were considered. The first was the 1: I million soil map of Europe, which includes information on slope angle for each soil class. This, however, was regarded as inadequate since the slope classes were too broad - only three classes (< 7, 7 to 15, > 15%) are recognized - and the spatial resolution too poor (the average map unit is around 130 km,).

The second source was digital terrain models (DTMs). These consist of a set of estimated spot heights, normally derived from satellite imagery or topographic maps, together with triangulation algorithms to convert the data to three dimensional surfaces. From these, it is possible to calculate slope angle. DTMs exist for a number of countries in the European Community, including Spain, Portugal and France. Problems of budget prevented their use in France, but the IGN in Madrid agreed to produce data on slope angle at a 1-km grid scale for both Spain and Portugal. These data are known to have a number of limitations: there is a significant (though unquantified) error in altitude, while the density of measured points in Portugal is only about one-tenth of that in Spain. Lacking any other compatible source, however, they were accepted as the best data available. After some difficulty due to inconsistencies in data and tape formats, the data were therefore registered to the 1:1 million scale CORINE geographic base.

The third means of obtaining slopes data was by the analysis of topographic maps. A partial analysis of the European Community had already been carried out by Professor I.B.F. Kormoss of the College of Europe in Bruges. This, however, covered only the area between 300 and 1 000 metres above sea level, in the original six Member States. The classification used was also not wholly consistent with that required for the CORINE soil erosion risk/land quality project. Nevertheless, it demonstrated the feasibility of slope mapping from topographic maps, provided a well-tested methodology, and gave a core of data on which the project could build. For those countries for which DTMs were not available, the decision was therefore taken to collect slopes data through the interpretation of topographic maps (Figure 3.11).

The procedure used was a simplification of that originally developed by Professor Kormoss. Analysis was based on *1:50* 000 scale topographic maps or their nearest equivalent (1: 100 000 in Italy, and 1:100 000 and 1:200 000 in Greece). Slope angle was calculated by counting the number of contours in each 1-km grid square along a 1-km transection laid north/south, east/west, and/or (for the purpose of checking) diagonally to coincide as near as possible with the line of greatest slope. Slope angles were expressed as percentages, and transferred to a grid map drawn on a UTM projection. In areas where contours were not visible (e.g. in urban areas), a 'missing value' was recorded. Lakes and cliffs (where contours were replaced by hachuring or other symbols) were also excluded from the analysis.

In this way, the original mapping of Kormoss was extended to the remainder of southern France, Italy and Greece. Areas previously classified into slope classes not directly compatible with the soil erosion risk/land quality assessment were also re-analysed and the slope angle recalculated. lt should nevertheless be noted that due to differences in the contour intervals of the maps (from 10 m to 50 m) significant discrepancies in the accuracy of these assessments may occur from one country to another. For regions with small but steep slopes, the 50-m contour interval plays a role in smoothing the relief (e.g. Monferrato, Italy). Comparisons between different Member States should therefore be made with care.

Data from this analysis were then encoded manually into a previously compiled input system, in dBASE 111 +. Each map sheet was entered as a separate block. Because map edges did not necessarily coincide with the 1-km grid, however, data for some strips had to be transferred to adjacent blocks to make up a uniform, rectangular area.

The geographic coordinates for the four corners of each block were then calculated from the topographic maps, to provide a spatial reference. An automatic check was then carried out to eliminate 'impossible values' in the encoded data, and a sample (around 10%) of all grid squares was checked to identify other encoding errors. After checking, data were transmitted on floppy discs for integration into the CORINE database.

Integration was a complex procedure. First, a reference corner coordinate (lower left) for each block was input and located on the CORINE topographic base. The block was then defined by projecting the grid cells in that block from this origin. Next, any discrepancies, gaps or mismatches in the blocks were identified and corrected. This involved a range of procedures, checks and revisions including:

( identifying and correcting errors in the corner coordinates or in the encoding of the data;

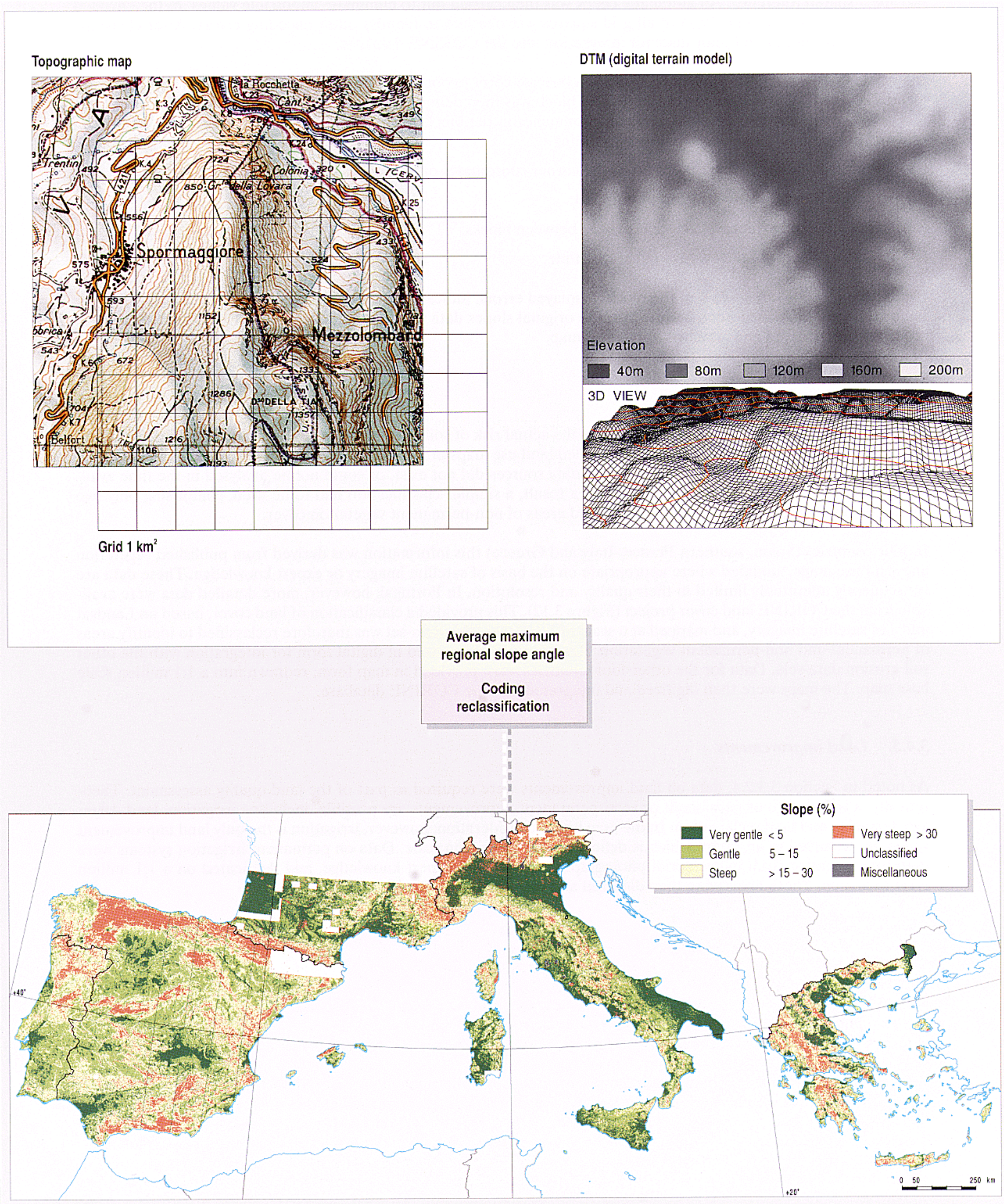
(ii) averaging cells where blocks overlapped;

(iii) interpolating values where gaps existed between blocks;

(iv) fitting the grid cell coverage to the coastline.

It may be noted that about 25% of the blocks displayed errors, indicating the difficulties of acquiring accurate data by the manual methods used here.  Meanwhile, the original slopes data were classified according to the assessment procedure, then imported and attached to the grid map.

Figure 3.11 - Derivation of the slope map



## 3.4.4. Vegetation cover

Data on vegetation cover were needed to assess the actual risk of soil erosion under present land use conditions. Ideally, these data should have been based on detailed land use maps or remotely sensed imagery, allowing the definition of a range of land use classes. In practice, such data sources did not exist, or could not be analysed in the time available, for most of the countries under study. As a result, a simpler classification had to be used, comprising only two classes: areas of permanent vegetation cover, and areas of non-permanent vegetation cover.

In four countries (Spain, southern France, Italy and Greece) this information was derived from published vegetation and land use maps, modified where appropriate on the basis of satellite imagery or expert knowledge. These data are consequently admittedly limited in their quality and resolution. In Portugal, however, more detailed data were available from the CORINE land cover project (Figure 3.12). This provided a classification of land cover, based on Landsat and TM satellite imagery, and mapped at a scale of 1:100 000. This data-set was therefore reclassified to identify areas of permanent and non-permanent vegetation. Results were transmitted in digital form for integration with the other soil erosion data-sets. Data for the other four countries were provided in map form, redrawn into a 1:1 million scale base map. The maps were then digitized and integrated into the CORINE database.

### 3.4.5. Land improvements

As noted in Section 3.3.2.4, data on land improvements were required as part of the land quality assessment. Theoretically, a wide range of permanent or semi-permanent improvements are possible, including irrigation, land drainage, terracing and land reclamation. In the area under consideration, however, irrigation is the only land improvement which has occurred to an extent which is definable at a 1:1 million scale. Data on permanent irrigation systems were therefore compiled from maps, aerial photographs, reports and expert knowledge, and delineated on a 1:1 million scale base map. These maps were then digitized and integrated into the CORINE database.

## 3.5. Data analysis and overlay

## 3.5.1. Data integration

Each data-set was registered to, and compiled on, the reference CORINE geographic base, at a scale of 1:1 million and in Lambert azimuthal projection (Table 3.1). The general steps involved are indicated in Figure 3.13. As noted in the preceding sections, however, integration procedures varied according to the specific characteristics of the individual data-set: in particular, the medium on which it was supplied, its format, geographic structure, scale and data type.

Table 3.1-The CORINE reference projection system

| | | | |
|---|---|---|---|
| Projection: | Lambert azimuthal | Latitude of centre of projection: | 48 00 00 N |
| Spheroid: | International 1909 | False easting: | 00 00 00 |
| Radius of spheroid of reference: | 0 | False northing: | 00 00 00 |
| Longitude of centre of projection: | 09 00 00 E | | |

Figure 3.12 - Derivation of the vegetation cover map

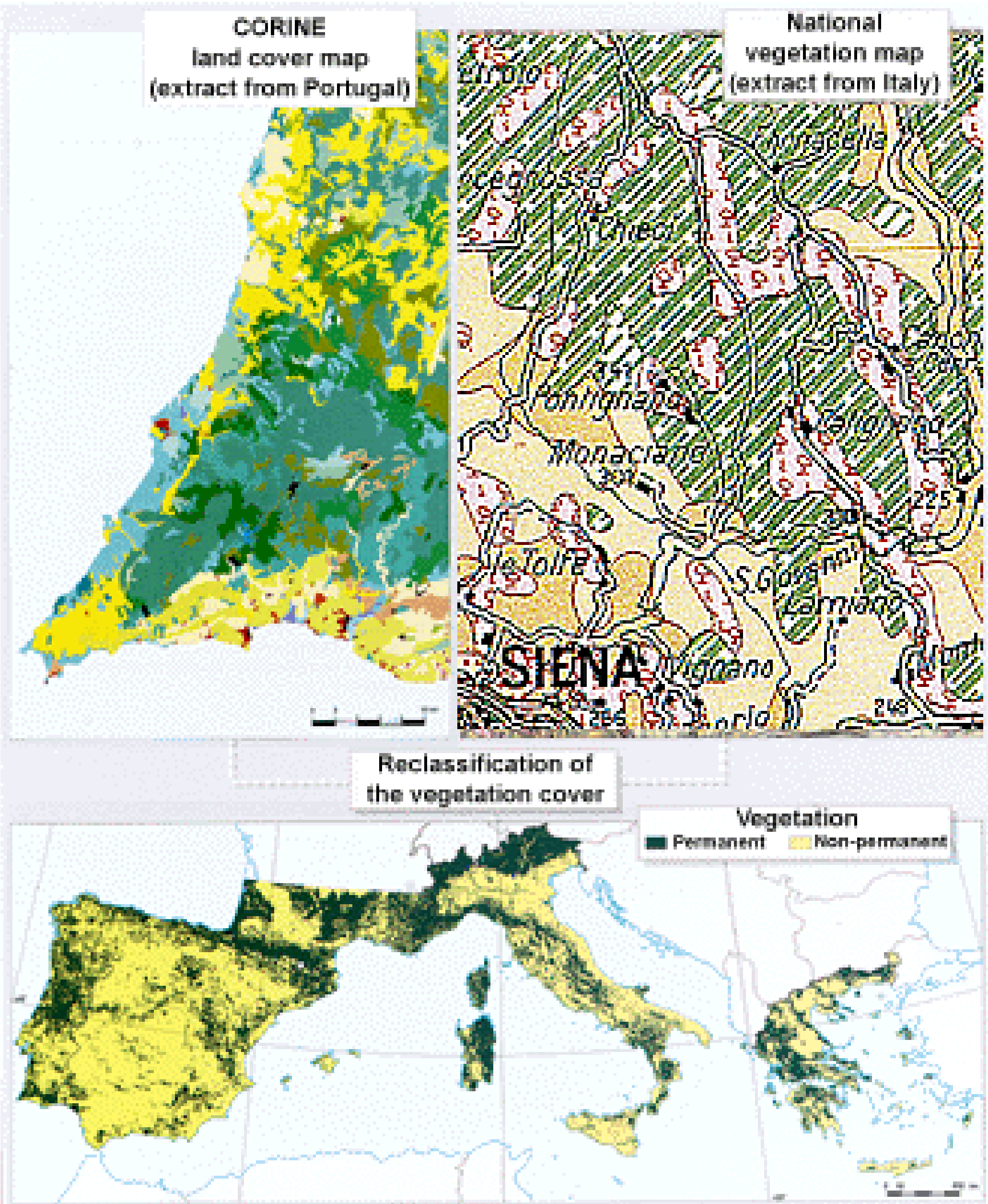


Figure 3.13 - Integration and overlay procedures in the analysis of soil erosion risk

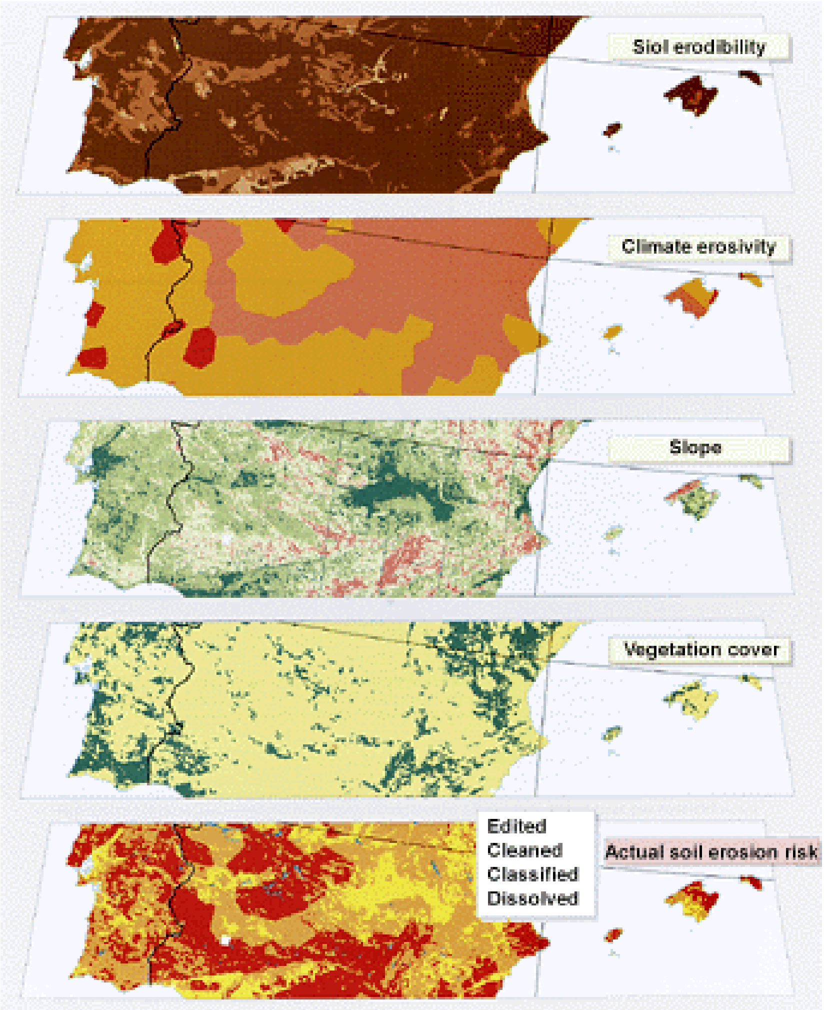


Figure 3.14 - Overlay of vector data, showing creation of sliver polygons

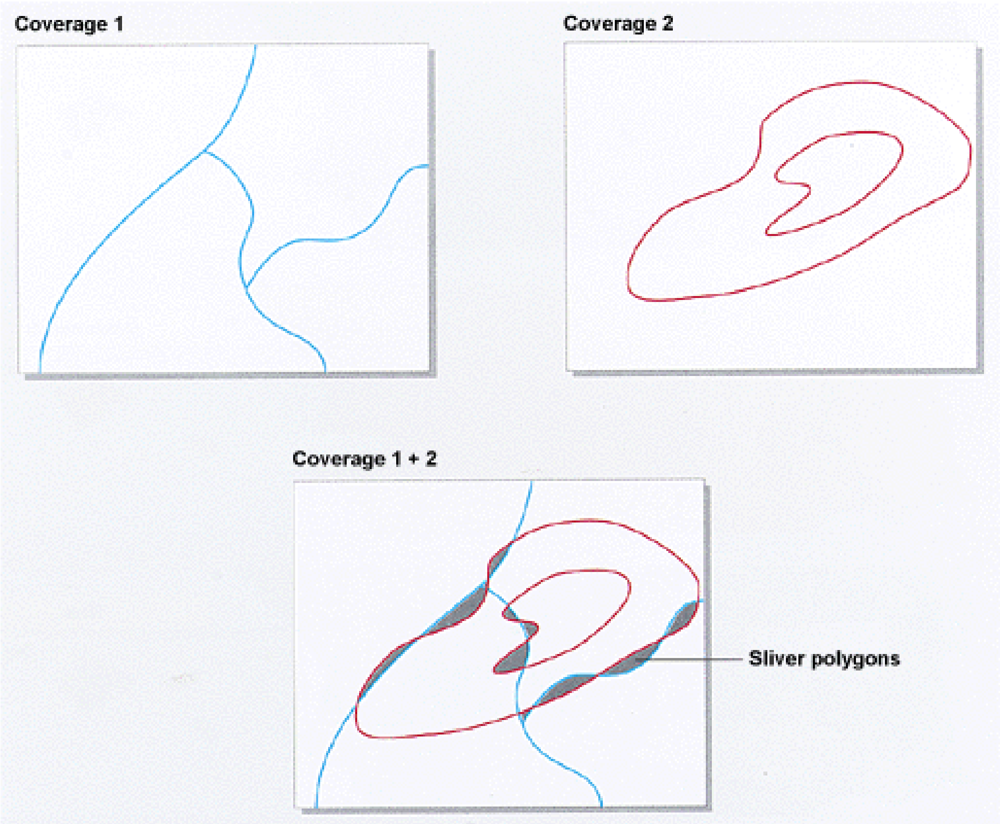
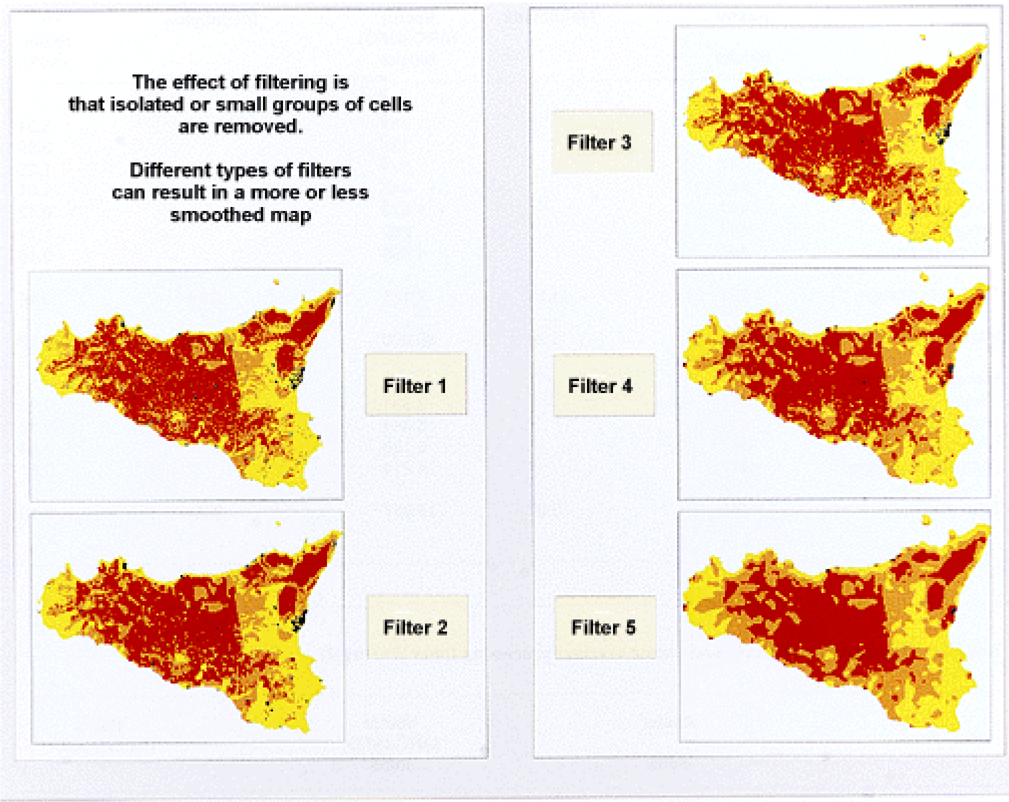



Figure 3.15 - Creation of 'noise' during raster overlay and the effects of filtering: the example of Sicily



### 3.5.2. Preliminary data analysis

Once integrated, the different coverages were overlaid, in accordance with the soil erosion risk and land quality models to derive new coverages (e.g. potential soil erosion risk, actual soil crosion risk). Several characteristics of the data being used made this a complex process. First of all, data volumes were large: the soils coverage alone amounted to around 10 megabytes, while the complete data-set on slope angle totals over 140 Mb. Analysis therefore demanded large amounts of disc space and CPU time.

Secondly, the geographic structure of the data is complex, with a large number of polygons in each data-set. The soils coverage (soil quality and soil erodibility), for example, each contained around 5 000 polygons. The slopes coverage comprised some 1.2 million grid cells, giving about 100 000 polygons after classification. This, too, had considerable implications for data volumes, processing times and disc storage during analysis. Thirdly, whereas the other data-sets were in vector form the slopes data were in raster form. Choice must therefore be made about whether to carry out the overlay in raster or vector form. Each has its advantages and disadvantages.

Processing in vector form retains the original structure of the data, but tends to create large numbers of sliver polygons, where overlaid polygons do not quite coincide (Figure 3.14). This may result in the generation of large and complex databases. Moreover, elimination of the slivers in a vectorial system, without losing vital information, can be a complex and time-consuming procedure.

Processing in raster form reduces these problems of sliver polygons, but may create other difficulties. In particular, raster overlay typically generates a large amount of 'noise' in the form of isolated cells, scattered across the map area, which do not conform to their surrounding classes (Figure 3.15). These may be filtered out, but in the process important information may again be lost. To retain the original spatial structure of the data - and to avoid creating artificially regular boundaries - it is also important that rasterization is based on sufficiently small grid cells. This, however, may itself generate large data volumes.

In order to evaluate alternative methods of overlay, tests were carried out using data from Crete and Sardinia. Overlay was conducted in both raster and vector form and the results, and analytical problems, compared. In terms of the quality of the output at that scale, no clear advantage was evident for either method. Further trial overlays were therefore produced for the whole of Greece, Italy and Portugal using vector methods. To achieve this, the slopes data were first vectorized, and then the various coverages overlaid as shown in Figure 3.13. These tests showed that raster processing resulted in a major saving of both CPU time and disk space requirements (Table 3.2 and Table 3.3). Final analysis was therefore conducted wholly in raster form.

Plots of both the individual coverages, and the combined results (potential and actual soil crosion risk, potential and actual land quality) were then submitted to the project team for validation. At this stage a number of errors and in-

consistencies in the data emerged, mainly relating to mistakes in the initial application of the assessment methodology, or miscodings during data capture.

Where necessary, the input data were therefore checked and corrected. Overall, however, the results confirmed the validity of the methodology, and indicated that the broad patterns of soil crosion risk and land quality were realistic.

Table 3.2-Comparison of raster and vector overlay:disk space requirements (Portugal)

| | **Raster blocks** | **Megabytes** | **Vector (ARC/INFO) blocks** | **Megabytes** | **Ratio raster/ vector** |
|---|---|---|---|---|---|
| **Origin data storage** | | | | | |
| Erosivity | 447 | | 135 | | 3.31 |
| Climate quality | 447 | | 132 | | 3.39 |
| Erodibility | 447 | | 371 | | 1.20 |
| Soil quality | 447 | | 443 | | 1.01 |
| Vegetation cover | 447 | | 1 073 | | 0.42 |
| Irrigation | 447 | | 262 | | 1.71 |
| Slope angle | 447 | | 4 705 | | 0.10 |
| Total data storage | 3 129 | 1.53 | 7 121 | 3.48 | 0.44 |
| **Intermediate disk space** | 10 728 | 5.24 | 9 280 | 44.08 | 0.12 |
| **Storage of results** | | | | | |
| Potential soil erosion | 447 | | 3 831 | | 0.12 |
| Actual soil erosion | 447 | | 3 884 | | 0.12 |
| Potential land quality | 447 | | 5 128 | | 0.09 |
| Actual land quality | 447 | | 4 214 | | 0.11 |
| Tota storage of results | 1 788 | 0.87 | 17 057 | 8.33 | 0.10 |

Table 3.3-Comparison of raster and vector overlay:processing times (Portugal)

| | **Raster mins** | **Vector (ARC/INFO) mins** | **Ratio raster/vector** |
|---|---|---|---|
| **CPU processing time** | | | |
| Potential soil erosion | n.a. | 160.0 | |
| Actual soil erosion | n.a. | 163.6 | |
| Potential land quality | n.a. | 170.5 | |
| Actual land quality | n.a. | 95.5 | - |
| Total CPU processing time | 31.1 | 589.5 | 0.05 |
| **Time loss in data transfer** | | | |
| Rasterization | 60.0 | 0.0 | - |
| Import into raster | 90.0 | 0.0 | - |
| **Total** | 181.1 | 589.5 | 0.31 |

### 3.5.3. Final analysis

All data were thoroughly checked for consistency of topology and attributes, in order to ensure that no data had been lost or changed during data transfer. Data originally missing due to their late arrival were added and integrated according to the same procedure as described above. In those cases where errors originated from obvious technical causes, corrections of geography, topology and attributes were made.

From each of the individual layers, colour maps were prepared and circulated within the project team and to the national experts concerned. Coding errors, geographical inaccuracies and inconsistencies between data layers were reported and corrected; a number of polygons were digitized and added or recoded. lt should be stressed that all such changes were carried out on the basic data layers to ensure consistency between basic data, methodology and results.

The verified data, in vectorial format, were afterwards rasterized in order to enable transfer to and analysis by a rasterbased system. This process was performed country by country (southern France, Greece, Italy, Spain and Portugal) and layer by layer (soil erodibility, climate erosivity, slopes, vegetation and irrigated land). Administrative boundaries and major settlements were also rasterized and transferred. The grid definition was chosen to cover completely the national territories with a grid of I km by 1 km. After transfer, test plots were made and data encoding verified on a raster-based system.

The overlay process itself, following the CORINE methodology, was a sequence of mathematical combinations and Boolean operations for the different data layers. If one of the layers had missing data it was necessary to exclude this area from the analyses, e.g: urban and non-mapped areas on the soil map, missing slope maps at the date of the actual overlay, sliver areas generated along the territorial boundaries due to registration dilterences between the data sources. Intermediate and final overlay results were plotted and examined. The results, being potential and actual soil erosion risk and land quality, were overlaid with the administrative boundaries and settlements in order to produce statistics per region and per country.

The efficiency and flexibility of this overlay in raster form were the actual reasons for performing this overlay in that manner. Response times for pure overlay operations were typically one to two orders of magnitude faster in the raster system as compared to vector GIS. This fast overlay procedure in raster format counterbalanced the overhead of data conversions and data transfer needed to bring data from vector to raster format and back to vector. However, the main advantage of overlay analysis in raster format is its greater flexibility and the on-line character of the procedure. Greater flexibility is clear since this kind of overlay analysis is typically iterative in nature, whereas verifications and corrections have to be done at several interim stages. The on-line character of raster overlays, with response times in the order of magnitude of minutes for individual interim overlays, renders the system interactive such that the effects of parameter classification or threshold values can be evaluated. lt enables the expert to obtain a clearer insight of the basic data, and to better understand the relationships between the different layers and their weight in the final results.

Due to different levels of accuracy in the basic data, the overlay results contained a large number of isolated and small areas. The slopes data, for example, relate to grid cells of only 1 km, compiled at a scale of 1:100 000. The soil, vegetation and irrigated land maps are the next most detailed at scales of about 1:1 000 000. Finally the climate areas and administrative boundaries data have the lowest resolution at scales of 1:3 000 000. The difference in registration accuracy for these maps inevitably resulted in a number of small, wrongly evaluated areas at the boundaries common to different data layers.

The smaller cells and areas registered at the highest resolutions are not relevant at the scales of publication of these maps, and render the image noisy. Visual appreciation can be improved by eliminating these small areas. This was done by using a filtering algorithm, based on a neighbouring cell majority criterion (3 by 3 filter). lt must be mentioned that territorial boundaries, urban areas and lakes were excluded from the filtering process.

In a following phase of data processing, raster data were transferred back to the vectorial system. The results for the individual countries were subsequently edge-matched to each other. These final results were used for high quality cartographic presentations and map printing.

# 4. Results

The development of this methodology, its application to the whole of the southern region of the Community (where problems of data availability are acknowledged as being at their most severe) and the successful generation of a set of mapped results represents a considerable attainment. lt also demonstrates that international collaboration and agreement on the question of land resources can he achieved, as long as a clear framework and set of objectives are provided.

From this exercise a range of results has been produced. These results can be seen to comprise three main sets of output:

(i) a set of procedures for the assessment of land quality and soil erosion risk for the Mediterranean region;

(ii) a database containing geo-referenced data on relevant aspects of the soil, climate, topography, vegetation cover and land improvements;

(iii) a set of maps and statistics presenting the results of the assessments throughout southern areas of the European Community.

In addition, the project has helped to forge a team of experts with wide-ranging experience of land resources and soil erosion in southern Europe, and has generated a network of contacts and collaboration throughout the Community.

This section outlines the main features of the results achieved so far. Subsequent sections illustrate the general lessons learned, the specific applications of the results and possible future developments.

## 4.1. Methodology

## 4.2. Database

## 4.3. Mapped outputs

## 4.1. Methodology

The methods developed for the assessment of land quality and soil erosion risk have been described in detail in the previous section.

As this indicated, the methods reflect an attempt to produce a compromise between the need for scientific rigour, on the one hand, and the constraints of practicality (especially data availability) on the other. It is worth noting that this is probably the first occasion on which such a methodology has been developed and applied in a transnational context of this kind. Nevertheless, the methodology has known weaknesses and limitations, and in future could be improved (see Chapter 7).

It is also notable that, as part of the project, various tests have been carried out on methods of aggregation and overlay, using GIS techniques. Indeed, the exercise has probably provided one of the most demanding tests of GIS in an application of this sort. In this context, it has allowed different assessment models to be evaluated, and the methodology to be refined and adjusted accordingly.

Additionally, it has enabled comparison of the efficiency of different overlay techniques and has, for example, illustrated the general advantage of raster approaches for large and complex data-sets such as these. At the same time, it has also shown the need for qualitative filtering of the results after overlay to remove noise from the data.

Table 4.1 CORINE data-sets created by the project on soil erosion and important land resources

| Data-set | Item | Scale | Description | Source |
|---|---|---|---|---|
| **SOILS** | Soils of Greece | 1:1 million | Soil map units : boundaries and classification | New map produced by Prof. Yassoglou |
| | Soil depth | 1:1 million | Average soil depth (3 classes) | Interpretation of 1:1 million soil map of EC and new soil map of Greece |
| | Soil texture | 1:1 million | Average soil texture (3 classes): 2 classifications, one relating to soil quality , one to soil erosion risk | As above |
| | Stoniness | 1:1 million | Average surface cover of stones (2 classes) | As above |
| | Soil drainage status | 1:1 million | Average soil drainage | As above |
| | Soil quality | 1:1 million | Map unit boundaries and classification (4 classes) of average soil quality | As above |
| As above | Soil erodibility | 1:1 million | Map unit boundaries and classification (4 classes) of average soil quality | |
| **CLIMATE** | Climatic | Point and 1:1 million | Point locations and polygon boundaries | Generation of Thiessen polygons around point locations |
| | Fournier index | Point | Fournier index (value and class) for climatic stations | Analysis of national meteorological data |
| | Bagnouls-Gaussen aridity index | Point | Bagnouls-Gaussen aridity index (value and class) for climatic stations | As above |
| | Vegetative period | Point | Length of vege tative period (value and class) for climatic stations | As above |
| | Frost index | Point | Index of frost severity (value and class) for climatic stations | As above |
| | Climate quality | Point | Climatic quality (3 classes) for climatic stations | Derived from analysis of input data |
| | Erosivity | Point | Erosivity (3classes) for climatic stations | As above |
| **VEGETATION** | Vegetation cover | 1:1 million | Boundaries of permanently vegetative areas | Compiled from various national maps and reports |
| **LAND IMPROVEMENTS** | Land improvements | 1:1 million | Boundaries of areas of permanent irrigation | As above |
| **TOPOGRAPHY** | Slope angle | 1:1 million | Average slope angle of each 1 km grid square | Analysis of topographic |

maps and DTMs

## 4.2. Database

All the data collected in the course of this project have been encoded or digitized and stored within the CORINE database. A summary of the data-sets concerned is given in Table 4. 1.

As this indicates, the project has provided a considerable range of basic data, much of it previously not available in a consistent and collated form for the area under study. These data thus give the opportunity to re-run the analysis and to carry out necessary improvements in the methodology. They will also be suitable for other evaluations of land resources in the Mediterranean region, as the need arises. In addition, they provide a standard for future data-collection exercises both in the European Community and its Member States. Above all, however, the combination of these land resource data with further information from the CORINE and other databases - either now or in the future - will open up the possibility for a wide range of new analyses of land use and ecological systems.

As with all geographic information systems, the real value of the data lies not in their separate application but in the potential for cross-fertilization which they offer.

## 4.3. Mapped outputs

Maps were produced as part of this project of each separate factor in the assessment methodology, as well as the derived results. All maps were plotted on the CORINE reference base map, at a scale of 1:1 million. Sets of maps for each Member State were provided to the relevant members of the project team for checking and interpretative purposes. A full plot of the results, covering the entire area of the southern Community countries was also produced for use in DG XI.

Summary maps and tables are presented below. These relate to the following indices:

| | *Soil erosion* | *Land resources* |
|---|---|---|
| **Basic layers** | Soil erodibility<br>Rain erosivity<br>Slope angle | Soil quality<br>Climate quality<br>Slope angle |
| | Vegetation cover | Land improvements (irrigation) |
| **Overlays** | Potential soil erosion risk | Potential land quality |

### 4.3.1. Potential soil erosion risk

### 4.3.2. Actual soil erosion risk

### 4.3.3. Potential land quality

### 4.3.4. Actual land quality

## 4.3.1. Potential soil erosion risk

Potential soil erosion risk is defined as the inherent risk of erosion, irrespective of current land use or vegetation cover. A map at potential risk therefore represents the worst possible situation that might be reached.

The situation in the southern Community varies considerably between countries, but substantial variability in erosion risk is also apparent at regional level (Figure 4.1).

As can be seen, around 35% of the rural land surface of the southern Community countries falls in potential erosion class 3 (high risk), 31 % in class 2 (moderate risk), 26% in class 1 (low risk).

The distribution of erosion risk is complex. Large areas of high risk occur in Portugal (68% of the rural ' land surface) and Spain (41%), largely determined by the variation in soil conditions and erodibility. A clear band of high erosion risk also follows the mountainous region of the Pyrenees, along the border between Spain and France; elsewhere in France, however, the potential for soil erosion is limited, and over 49% of the country is classified as having a low erosion risk. In Italy, too, areas of high potential erosion risk tend to follow the mountainous land of the Alps and Apennines, reflecting the important control exerted by topography on both slope angle and climate. Areas of high risk also occur in Calabria, Sicily and Corsica, associated primarily with areas of high rainfall erosivity and mountainous terrain. In total, around 27% of Italy is defined as high erosion risk. Conversely, areas of low erosion risk tend to coincide with

the lowlands: in the Po valley, the 'heel' of Italy and along the coastal plain - amounting in total to almost 41% of the country. In Greece, 43% of the land is classified as having a high potential erosion risk, mainly in the south and west, where soils, terrain and climate combine to create suitable conditions. A little over 20% of the country is, in contrast, of low erosion risk, mainly in a broad belt through Macedonia, the Pelopponese and Thessaly.

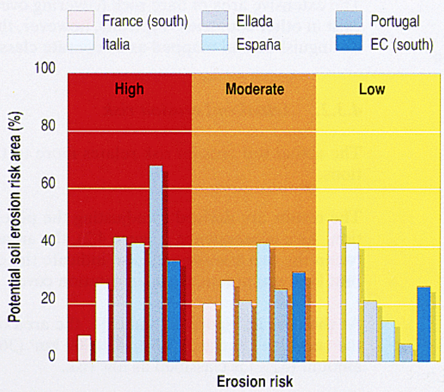
The extensive area of bare rock (covering over 10% of the land area) is also notable in Greece. Areas of bare rock also exist in other countries. Typically, however, they occur as small, localized patches of land and, for this reason, were not distinguished and mapped as a separate class.

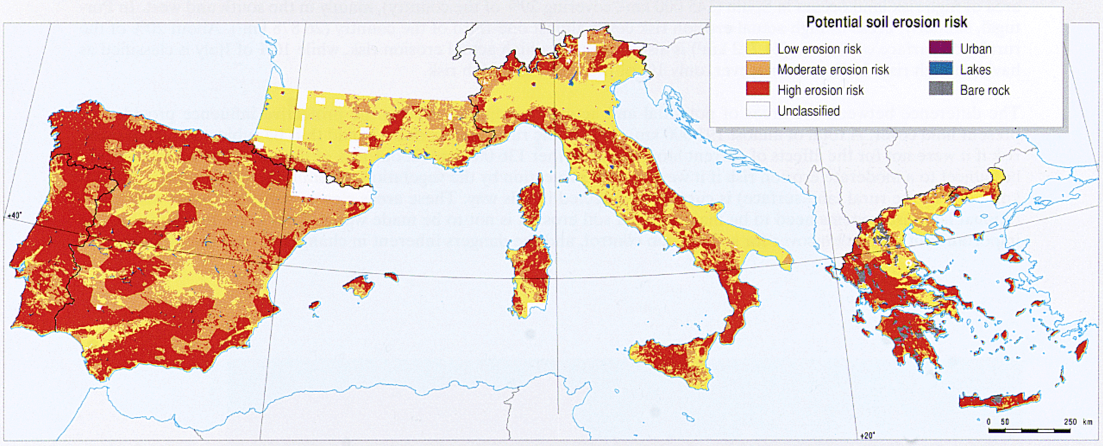
Figure 4.1 - Potential soil erosion risk in southern Community countries

**Potential soil erosion risk: National data**

| Country | High risk area | | Moderate risk area | | Low risk area | | Excluded area [2] | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | km² | % | km² | % | km² | % | km² | % | km² |
| France (south) | 16 355 | 9 | 37 900 | 20 | 93 443 | 49 | 42 463 | 22 | 190 161 |
| Italia | 82 348 | 27 | 85 211 | 28 | 122 416 | 41 | 11 303 | 4 | 301 278 |
| Ellada | 57 414 | 43 | 27 436 | 21 | 27 027 | 21 | 20 113 | 15<br>10% BR | 131 990 |
| España [1] | 202 101 | 41 | 205 157 | 41 | 69 662 | 14 | 20 598 | 4 | 497 518 |
| Portugal [1] | 61 120 | 68 | 21 890 | 25 | 4 918 | 6 | 1 000 | 1 | 88 928 |
| **EC (south)** | **419 338** | **35** | **37 759** | **31** | **317 466** | **26** | **95 477** | **8** | **1 209 875** |

[1] Without the islands
[2] Includes urban land, lakes, bare rock and area of missing data



## 4.3.2. Actual soil erosion risk

The actual soil erosion risk relates more to the current risk of erosion under present vegetation and land use conditions.

The results are derived by adjusting the potential soil erosion risk to allow for the protective influence of the vegetation. As a consequence (Figure 4.2), the areas of land at risk (especially class 3) tend to be lower. The differences between the two assessments also indicate the extent of land where the soil erosion risk is diminished as a result of current land use practices and vegetation cover.

As the data in Figure 4.2 indicate, the area of land with a high actual erosion risk totals 229 000 km² (around 19% of the rural land surface). Over 430 000 km, (36%) are classified as having a moderate actual erosion risk, and a similar amount (37%) is classified as low risk.

The distribution of the actual erosion risk broadly follows that outlined previously. In quantitative terms, the largest area of high risk land occurs in Spain (145 000 km², covering 29% of the country), mainly in the south and west. In Portugal, similarly, areas of high actual erosion risk cover almost one-third of the country (26 878 km,). About 20% of the rural land surface of Greece (24 712 km²) is also subject to a high actual erosion risk, while 10% of Italy is classified as having a high risk. In France, however, only 1% of the area has a high risk.

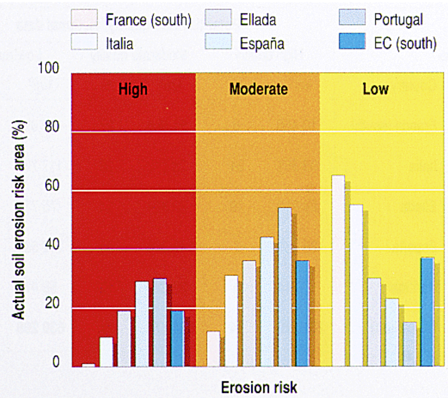
The difference between the areas of potential and actual erosion risk reflects the protective influence provided by present land cover. A total of almost 191 000 km² (17% of the rural land surface) would thus be subject to high erosion risk if it were not for the effects of current land use. A further 136 000 km² (about 11% of the rural land surface) would be subject to a moderate erosion risk if it were not for protection by the vegetation. Overall, therefore, almost 250 000 km² (28% of the rural land surface) is currently protected in this way. These areas clearly represent zones whose traditional land use systems need to be maintained if soil erosion is not to be made worse. They serve to emphasize the importance of vegetation cover for soil erosion control, and the dangers inherent in changes in land use practice.

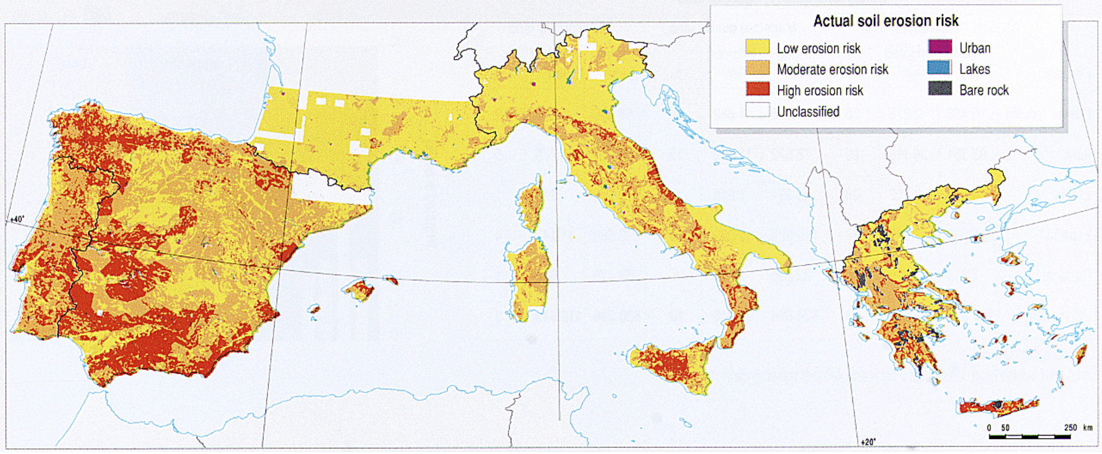
Figure 4.2 - Actual soil erosion risk in southern Community countries

**Actual soil erosion risk: National data**

| Country | High risk area km² | High risk area % | Moderate risk area km² | Moderate risk area % | Low risk area km² | Low risk area % | Excluded area [2] km² | Excluded area [2] % | Total km² |
|---|---|---|---|---|---|---|---|---|---|
| France (south) | 1 693 | 1 | 22 362 | 12 | 123 643 | 65 | 42 463 | 22 | 190 161 |
| Italia | 30 169 | 10 | 93 983 | 31 | 165 823 | 55 | 11 303 | 4 | 301 278 |
| Ellada | 27 713 | 19 | 47 877 | 36 | 39 287 | 30 | 20 113 | 15 | 131 990 |
| España [1] | 145 494 | 29 | 219 908 | 44 | 111 518 | 23 | 20 598 | 10% BR 4 | 497 518 |
| Portugal [1] | 26 878 | 30 | 48 166 | 54 | 12 884 | 15 | 1 000 | 1 | 88 928 |
| **EC (south)** | **228 947** | **19** | **432 295** | **36** | **453 155** | **37** | **95 477** | **8** | **1 209 875** |

[1] Without the islands
[2] Includes urban land, lakes, bare rock and area of missing data



## 4.3.3. Potential land quality

Potential land quality refers to the inherent physical quality of land resources for agriculture, biomass production, and vegetation growth. As shown in Figure 4.3, the majority of the Mediterranean region is classified as having a low potential land quality. This primarily reflects the limitations of slope, soil and aridity. Areas of high potential land quality occupy only 14% of the total land surface, mainly in Italy (93 400 $km^2$ covering 31% of the land area), Spain (35 300 $km^2$, 7%) and Greece (25 000 $km^2$, 19%). Notably large areas of high quality land are found in the Po valley and along the coastal plain of Italy; along the Tagus valley inland of Lisbon and in the Duoro valley around Porto in Portugal; in the coastal lowlands of Greece (e.g. Thessaloniki and Kavala); in the valley floors of the Rhone, Aude and Garonne in southern France; and in the coastal and estuarine regions of Andalusia. Many of these areas, significantly, are associated with areas of rapid urban extension and tourism development, and are thus likely to be at risk. Otherwise, most of the areas of high potential land quality occur as small, scattered pockets, often in association with small valley floors and basins which support more fertile soils. As such, many of these areas are also vulnerable to relatively minor local and regional developments, and clearly require careful monitoring if they are to be protected and conserved.

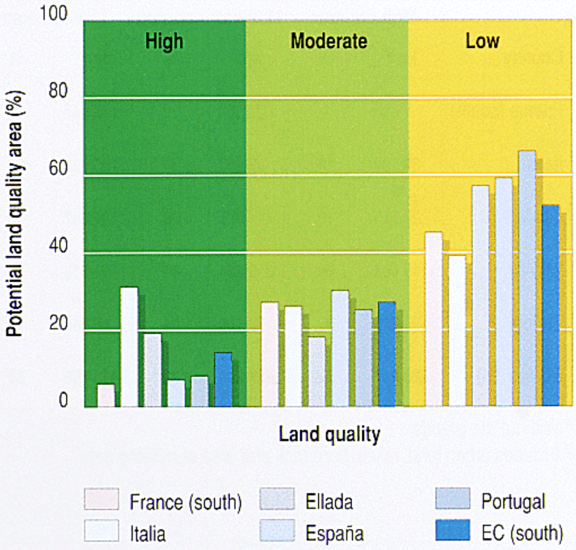
In contrast, 52% of the land area is classified as having a low land potential. This area covers much of Spain and Portugal, the central and eastern parts of southern France, the mountain areas of the Alps and Apennines in Italy, and much of the more hilly terrain in Greece. Despite its low land quality, however, much of this area is used for traditional, low-intensity farming systems which are important in maintaining the characteristic Mediterranean landscapes

They are also often of considerable ecological importance. In their own way, therefore, these areas present a vital resource which requires monitoring and protection.

Figure 4.3 - Land quality in southern Community countries

**Potential land quality: National data**

| Country | High quality km² | High quality % | Moderate quality km² | Moderate quality % | Low quality km² | Low quality % | Excluded area [2] km² | Excluded area [2] % |
|---|---|---|---|---|---|---|---|---|
| France (south) | 10 456 | 6 | 51 546 | 27 | 85 690 | 45 | 42 469 | 22 |
| Italia | 93 351 | 31 | 78 672 | 26 | 117 772 | 39 | 11 483 | 4 |
| Ellada | 24 919 | 19 | 23 394 | 18 | 75 775 | 57 | 7 903 | 6 |
| España [1] | 35 286 | 7 | 149 026 | 30 | 292 586 | 59 | 20 619 | 4 |
| Portugal [1] | 7 214 | 8 | 22 236 | 25 | 58 475 | 66 | 1 003 | 1 |
| **EC (south)** | **171 226** | **14** | **324 874** | **27** | **630 298** | **52** | **83 477** | **7** |

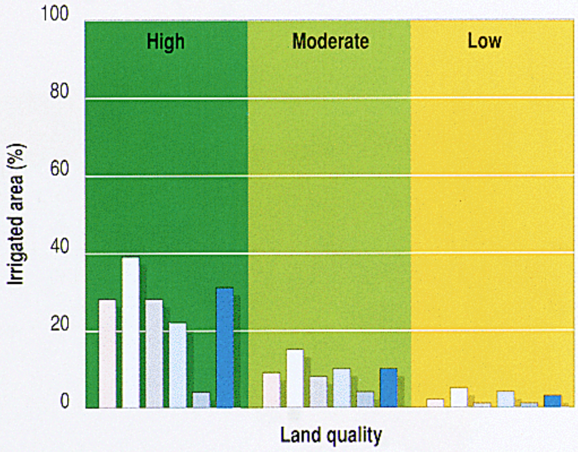


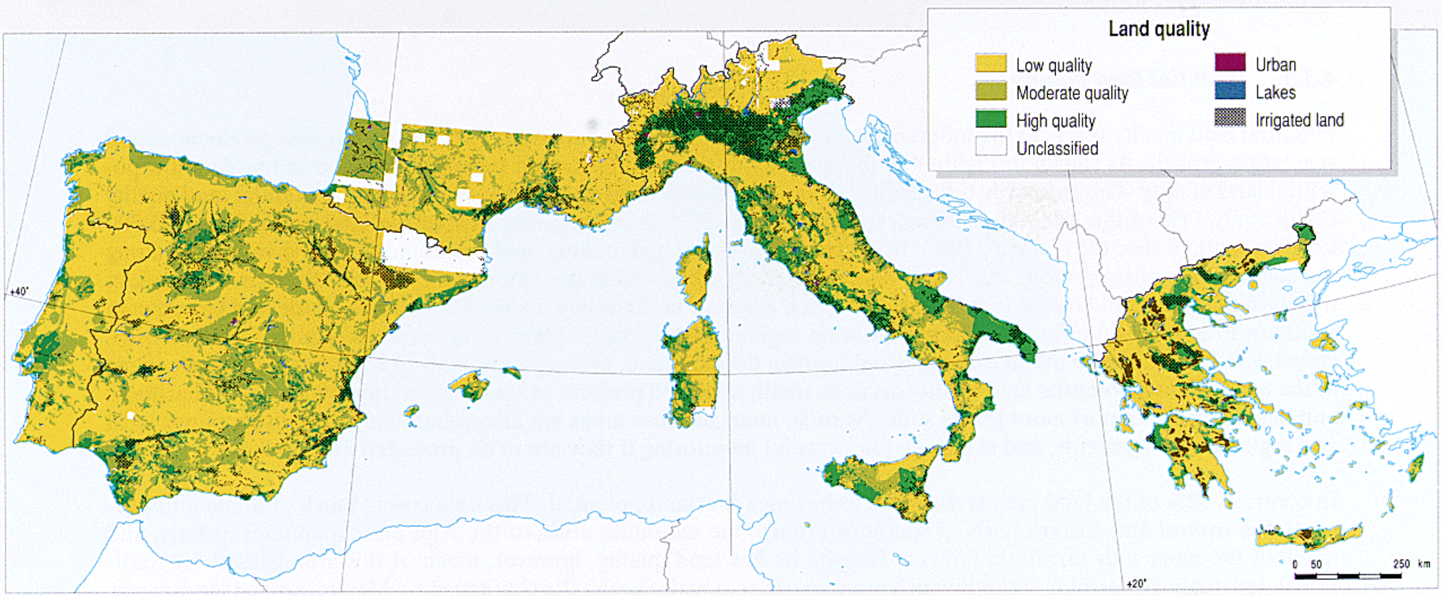

**Actual land quality: National data**

| Country | High quality land Total km² | High quality land Irrigated km² | High quality land % | Moderate quality land Total km² | Moderate quality land Irrigated km² | Moderate quality land % | Low quality land Total km² | Low quality land Irrigated km² | Low quality land % |
|---|---|---|---|---|---|---|---|---|---|
| France (south) | 10 456 | 2 878 | 28 | 51 546 | 4 882 | 9 | 85 690 | 1 306 | 2 |
| Italia | 93 351 | 36 118 | 39 | 78 672 | 11 490 | 15 | 117 772 | 5 770 | 5 |
| Ellada | 24 919 | 6 982 | 28 | 23 394 | 1 818 | 8 | 75 775 | 710 | 1 |
| España [1] | 35 286 | 7 615 | 22 | 149 026 | 15 059 | 10 | 292 586 | 11 147 | 4 |
| Portugal [1] | 7 214 | 273 | 4 | 22 236 | 796 | 4 | 58 475 | 616 | 1 |
| **EC (south)** | **171 226** | **53 866** | **31** | **324 874** | **34 045** | **10** | **630 298** | **119 549** | **3** |

[1] Without the islands

[2] Includes urban land, lakes, bare rock and area of missing data



## 4.3.4. Actual land quality

The actual land quality relates to the quality of the land under present management conditions, including permanent or semi-permanent improvements in the form of irrigation.

In total 107 500 km² of land have been improved by permanent irrigation systems with some significant differences between the countries (Figure 4.3). Most of this irrigation is concentrated, as might be expected, in areas of high potential land quality, where the economic returns from improvements are likely to be greater. Indeed, in these areas, irrigation is clearly an important aspect of agricultural practice: about one-third of the area is subject to permanent irrigation. In areas of low land quality, conversely, irrigation is relatively rare - generally only I to 5% of the area is irrigated. Nevertheless, it may be questioned whether even this small area of poorer land (if it has been correctly classified) is in fact suitable for irrigation.

The distribution of these irrigated soils is reasonably consistent throughout the region. Irrigation tends to take place primarily in lowland areas (on valley floors, in estuarine basins, etc.) where water is readily available and where other physical conditions are generally suitable for agriculture. Particularly broad areas of irrigation, for example, occur in the Po valley in Italy. Other important areas of irrigation tend to be associated with major conurbations, presumably supplying vegetables and other high value cash-crops to the local markets: for example, around Valencia in south-cast Spain and along the coastal plain between Marseilles and Perpignan in southern France. On the whole, however, areas of irrigation are small and localized, reflecting the scattered distribution of the high quality land in the Mediterranean region.

# 5. Applications

# 5.1. Uses of the results for land management

The CORINE information system - and the work of the CORINE programme as a whole - was conceived with the objective of guiding and informing environmental policy in the European Communities. The question must therefore he asked: to what extent can the results produced by this project contribute to this goal?

The answer is provided in part by the results which have already been described. The policy applications of these are readily apparent. They not only provide an inventory of land resources in southern Community countries, which is useful for general land planning purposes, but also supply a range of specific information about soil crosion risk and land quality which can he used to address a wide variety of policy issues.

## 5.1.1. Soil erosion control

## 5.1.2. Land conservation

## 5.1.3. Monitoring and research

## 5.1.4. Other applications

## 5.1.1. Soil erosion control

One of the main applications lies in developing Community policies on soil crosion control. As has been noted, soil crosion represents an important and costly problem in southern Europe: in the short term it results in damage to crops, loss of fertilizers, reduced yields, increased costs and loss of revenue for the farmers. in the longer term, it causes degradation of soil fertility and siltation of water courses and reservoirs. It may thus lead to extensive damage to the land resources of the region, with wide-ranging implications for farming and rural societies. One of the main concerns of the Community's environmental, agricultural and regional policies must therefore be the prevention and control of soil crosion. The question remains, however: what types of policies should he introduced, and where should they he directed?

Results from this project clearly help to tackle these questions. Figure 5.1 for example, shows the distribution of land with a high potential crosion risk. This comprises those areas where the natural conditions favour soil crosion - in other words, soil crosion in these areas is likely to occur whenever management practices do not provide active protection to the soil.

To be more compatible to the administrative approach used by other support programmes of the Community, the information can also he presented by overlaying the high crosion risk map with that for the administrative regions (NUTS 111). In this way, the percentage of each territory subject to high crosion risks becomes more apparent. As shown in Figure 5.2, 66 regions out of 254 situated in the southern part of the Community exhibit a potential high crosion risk in more than 60% of their territory. The same percentage of land exhibiting high crosion risk persists in 12 out of 254 regions when actual crosion is considered. This is either due to insufficient protection or to an inherent susceptibility.

The primary need in these areas is thus for positive soil crosion control: more detailed studies should therefore be undertaken on, for example, measures such as contour ploughing, bunding, mulch conservation and zero tillage. In extreme cases, there may also be a need for more fundamental changes in farming practices, such as a shift to pastoral systems. To facilitate the introduction of these measures, national and Community policies arc required which provide support (e.g. finance, advice) to farmers.

At the same time, there is a need for preventive policies which discourage rapid or insensitive development and land use change. This is exemplified by the information in Figure 5.3, indicating those areas where the current vegetation cover is instrumental in protecting the soil from crosion; and thus where vegetation removal is likely to exacerbate the crosion problem. Clearly, it is important in these areas to ensure that regional development, agricultural innovation or other activities do not lead to the damage or removal of this vegetation cover. Instead, policies are required which help to protect the vegetation and thus minimize soil crosion.

Soil crosion is not only a threat to agricultural land; equally it may threaten natural habitats. Conservation of natural vegetation not only protects wildlife; it may also help to prevent soil erosion. For these reasons, the spatial relationship between areas of soil crosion risk and biotopes is of considerable importance. Figure 5.4. shows the intersection of the two in Portugal. Where biotopes and soil crosion risk coincide, there we clearly see especially strong needs for careful management and conservation.

Figure 5.1 - Areas of high potential erosion risk in southern Community countries

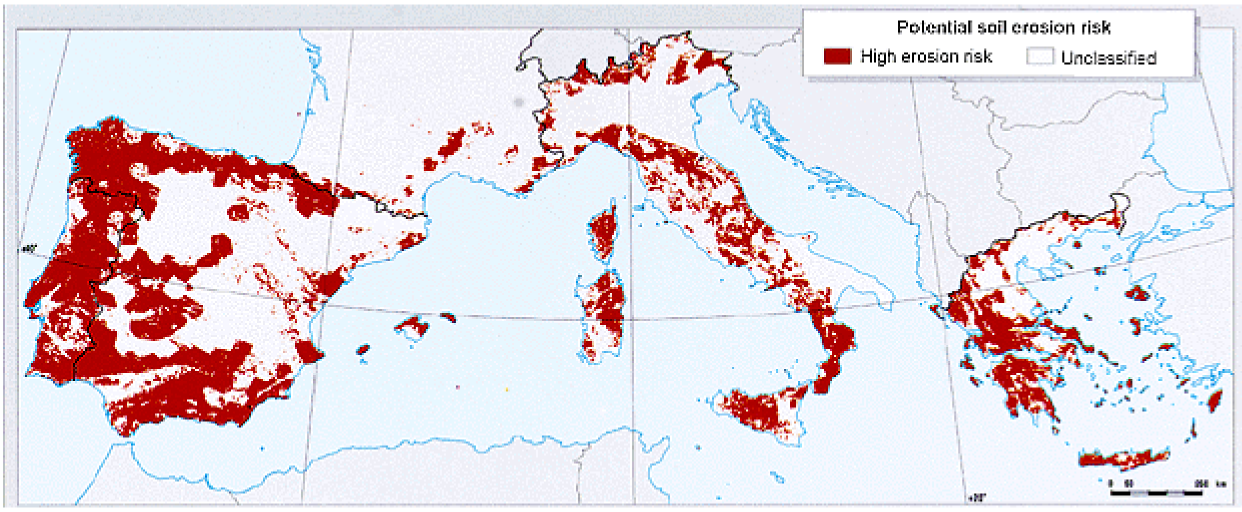


Figure 5.2 - Importance of potential and actual high erosion risks by administrative region (NUTS III)

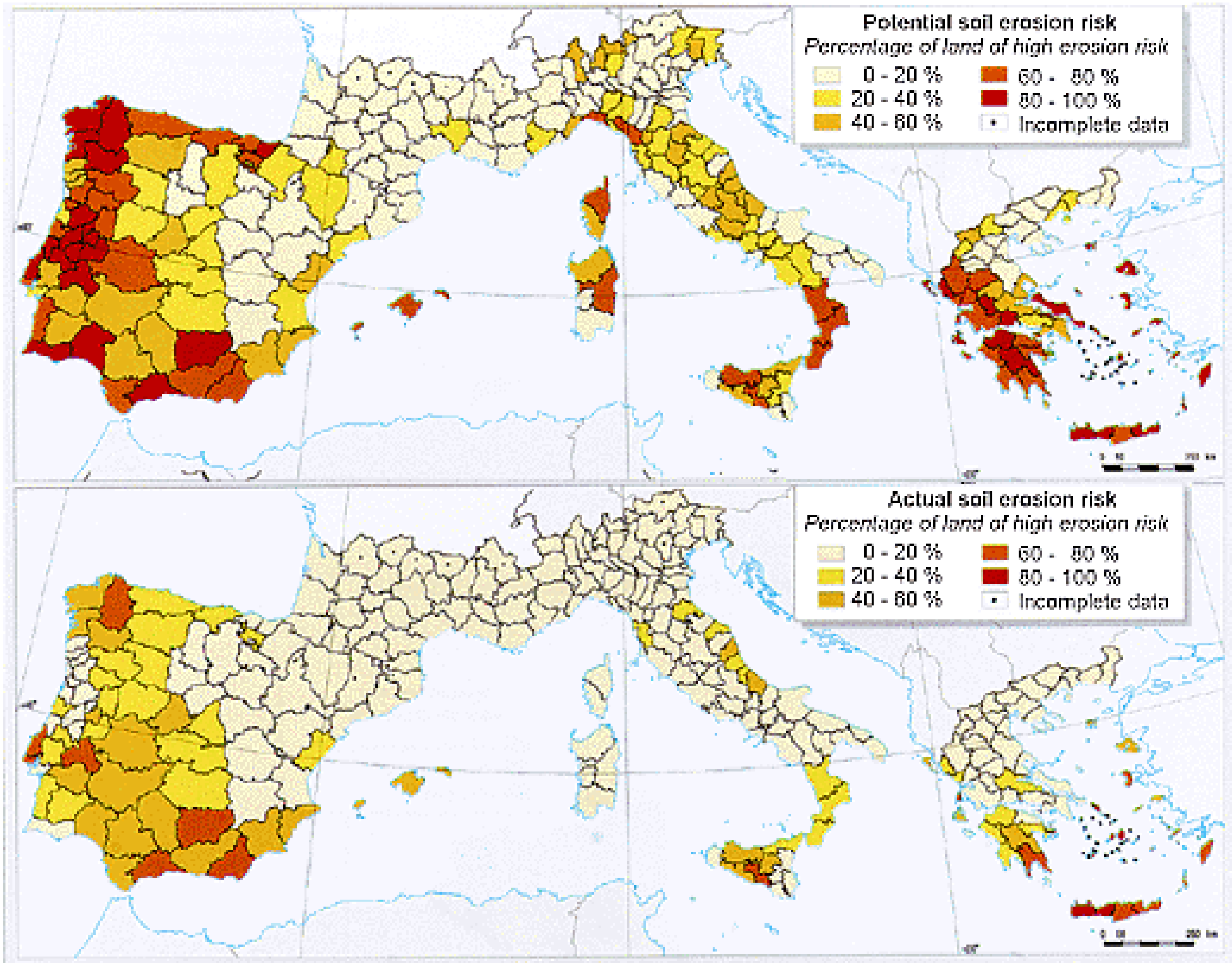



Figure 5.3 - Areas in which vegetation cover is crucial in providing protection against soil erosion

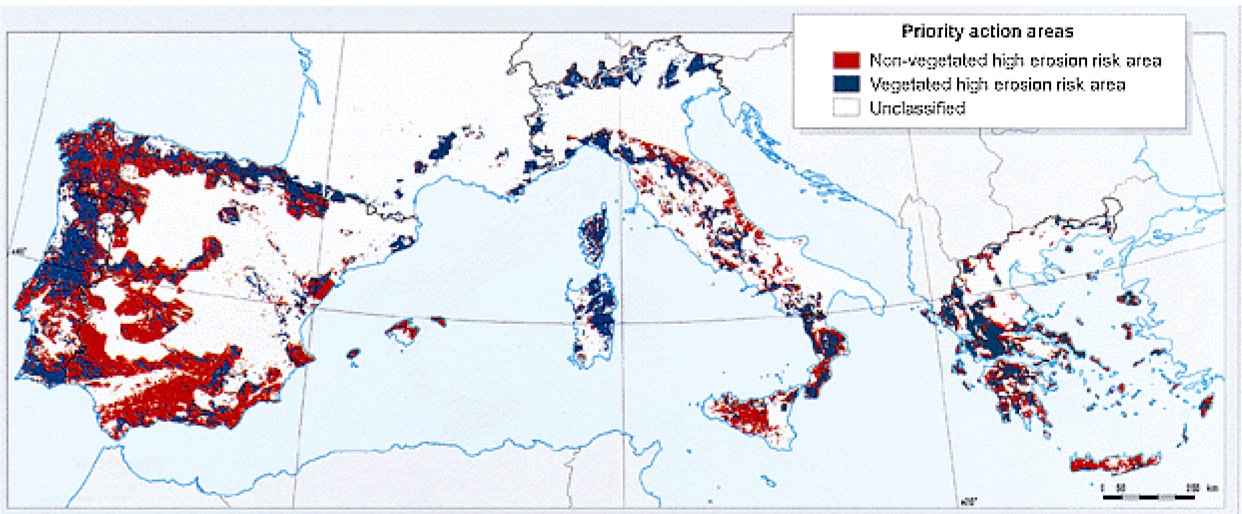


Figure 5.4 - Distribution of biotopes situated on high-erosion-risk soils in Portugal

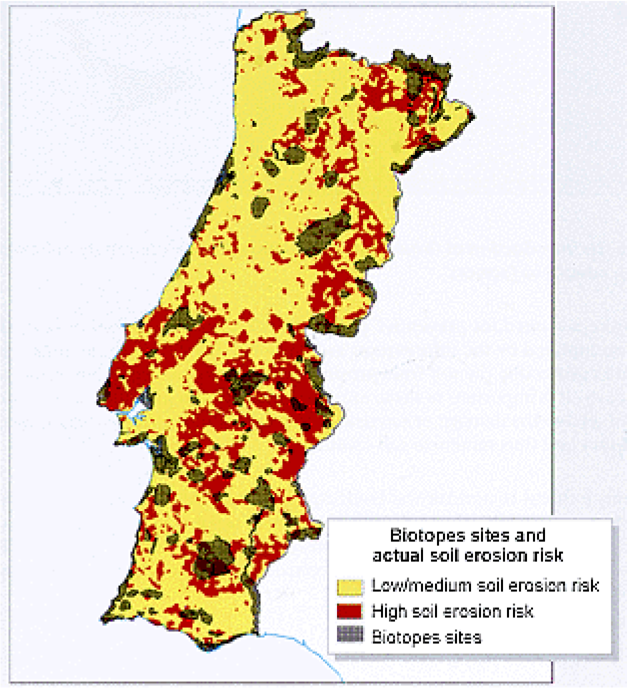
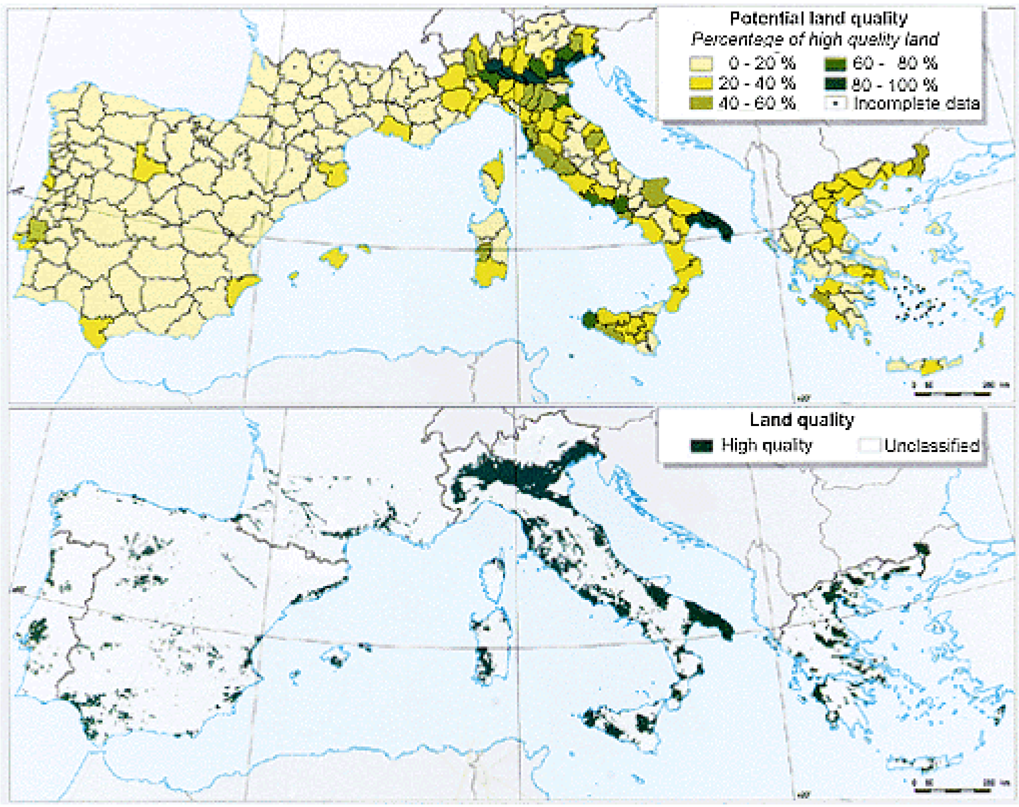



Figure 5.4 - Important land resources in southern Community countries: areas of high-quality land



## 5.1.2. Land conservation

The results from this project have similar applications in relation to the conservation of important land resources. As Figure 5.5 indicates, areas of high quality land are limited in extent and scattered in distribution in southern Europe. Consequently, they are both a scarce resource, and one which is vulnerable to insensitive developments. Over-intensification of agriculture, leading to soil degradation, may cause irreparable damage. Urban expansion, tourist development, mining or road construction may also threaten these areas.

Figure 5.6. shows the relationship between population change by administrative region from 1960 to 1986, and potential land quality in Portugal. As can be seen, a net shift of population has occurred, with a decline in the rural areas of the east and an increase in the coastal and urban areas of the west. Comparison with data on land cover, from the CORINE Land Cover database, also shows that urbanization tends to be concentrated on the areas of higher land quality (Figure 5.7).

Conflicts of interest in land management can be illustrated by overlaying different data-sets. Combining the map of high quality land in Portugal with that of biotopes, for example, distinguishes areas where irrigation development may threaten nature conservation (Figure 5.8). In contrast, where biotopes are associated with lower quality land, it may be anticipated that less intensive, more traditional farming practices will persist. In these areas, therefore, conflicts of interest are less likely to arise.

In order to protect these key land resources, it is vital that policy actions which might impinge upon these areas are carefully evaluated and their effects closely monitored. Regional policies which might encourage urban growth, or transport policies which promote highway development, for example, need to he rigorously analysed to ensure that they do not lead to the unnecessary loss of high quality land. Similarly, allocation of guidance funds under the CAP should be made in full awareness of the possible effects on these areas. Equally, more positive protective measures may also be required, including perhaps the designation of such areas as important land resources which Member States have a duty to conserve.

Figure 5.6 - Regional demographic changes in Portugal (1960-86) and potential land quality

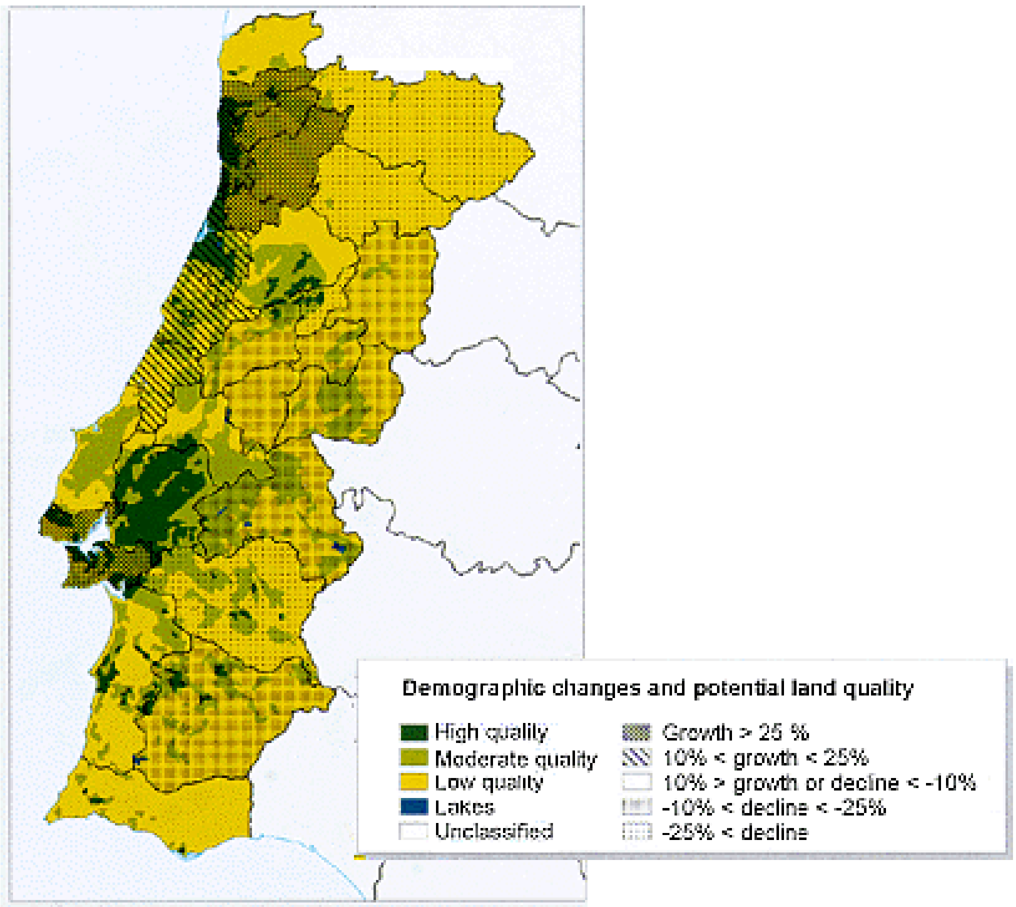
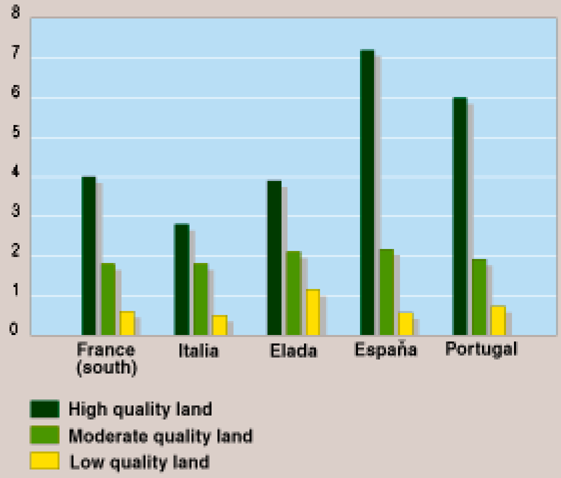


Figure 5.7 - Proportion of urbanized land according to different soil quality  types

| country | High quality % | Moderate quality % | Low quality % |
|---|---|---|---|
| France (south) | 4.0 | 1.8 | 0.6 |
| Italia | 2.8 | 1.8 | 0.5 |
| Elada | 3.9 | 2.1 | 1.1 |
| Espana | 7.2 | 2.2 | 0.6 |
| Portugal | 6.0 | 1.9 | 0.7 |

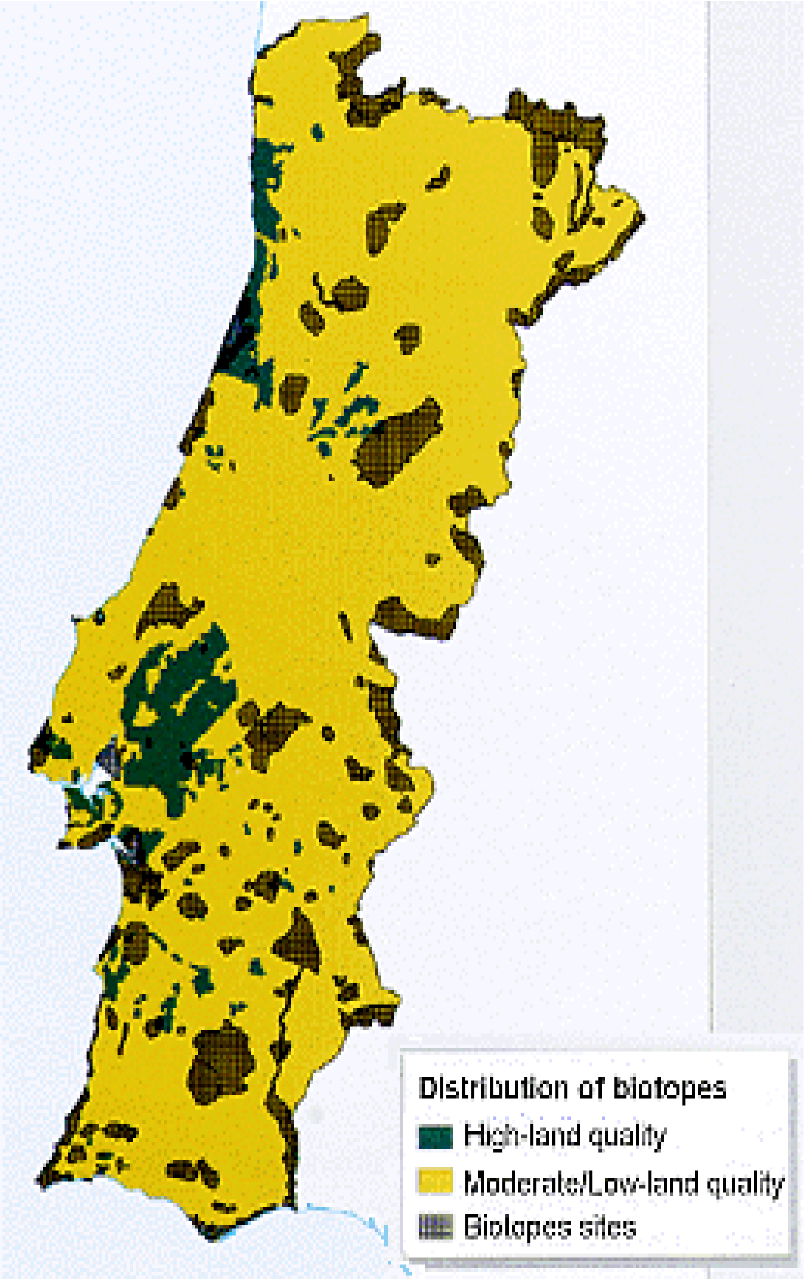
Source: CORINE estimations



## 5.1.3. Monitoring and research

In the same way, the results from this project can help to underpin and direct Community research. One of the particular needs in this context is for more detailed surveying and monitoring of land resources. The areas of important land resources, shown in Figure 5.5, for example, need to be monitored to keep track of changes in land use and to provide a warning of potentially adverse developments. Similarly, those areas where the vegetation cover is currently providing protection against soil crosion (Figure 5.3) need regular monitoring. In both cases, the methods developed in the CORINE land cover project are likely to be appropriate. In addition, the data on soil erosion risk indicate where more detailed studies of erosion processes and control measures can be carried out, or where demonstration projects may usefully he set up. The soil crosion maps can also act as an important input into studies on reservoir siltation or coastal sediment transfers.

Figure 5.8 - Distribution of biotopes situated on different soil quality types in Portugal



## 5.1.4. Other applications

These results, however, are far from the end of the story, for the raw data collected as part of this project - the data on soils, slope angle, climate, etc. - all have many other potential uses. All these data-sets can provide the basis for analysis of other policy-related issues; especially when combined with data on other themes.

Together with information on water pattern, for example, they can contribute to the analysis and modelling of water resources in southern Member States (e.g. predictions of stream discharge and runoff efficiency). Together with data on fertilizer usage and livestock densities, they can be used to help define potential water protection areas, where risks of nitrate pollution are unacceptably high. Together with data on land use and emissions they may help in the assessment of environmental sensitivity to acid deposition. Supported by more detailed climatic data, they provide the opportunity to assess and map land suitability for specific crops or management systems. As needs arise, undoubtedly, other users will identify many other applications. Examples are summarized in Table 5.1.

Table 5.1-Potential applications of the CORINE land resources database

| **Application** | **Procedure** |
|---|---|
| Definition of land resources requiring special protection | Interpretation of land quality and threatened land resources maps |
| Allocation of support for soil erosion control | Interpretation of soil erosion risk and threatened land resources maps |
| Estimation of risks of desertification | Analysis of soil erodibility, soil quality and climatic data |
| Modelling of the impacts of climatic change on land resources | Analysis of soil, land quality, topography, climatic and vegetation data to predict land surface climate interactions |
| Assessing broad-scale impacts of proposed regional development projects | Interpretation of soil erosion risk and land quality maps |
| Optimization of environmental benefits of extensification and set-aside | Interpretation of land quality and soil erosion risk maps, in association with data on biotopes |
| Definition of important land resources threatened by atmospheric pollution and/or acidification | Interpretation of soil and land resources data, in combination with data on atmospheric emissions |
| Development of policies for soil protection | Interpretation of land quality and soil erosion risk maps |
| Targeting of research on soil erosion | Interpretation of soil erosion risk maps |
| Predicting effects of soil erosion on reservoir siltation | Analysis of soil erosion risk data in combination with data on water pattern, topography, land use, etc. |
| Modelling of coastal sedimentation and erosion rates | Analysis of soil erosion risk data in combination with data on coastal erosion |
| Modelling of water resources and run-off potential | Analysis of soil, climatic and topographic data in combination with data on water pattern |
| Definition of water protection zones | Analysis of soil, climate and topographic data in combination with data on land use |

## 5.2. Limitations and constraints

This wide variety of potential uses of the data on land quality and soil erosion demonstrates beyond doubt the value of the information which has been gathered, and the important role it can play in developing Community policies on soil protection and land resources. As can be seen, these uses expand considerably as the possibility arises to combine the information with other data-sets.

Any such applications of the data, however, bring with them risks of misunderstanding and misuse. The data which have been collected in this project - like others in the CORINE information system - are complex, at times incomplete, and on occasion of uncertain reliability. Anyone using the data therefore needs to be aware of their limitations. The following sections highlight the major constraints of the data, and the factors which need to be taken into account in using them.

## 5.2.1. Climate

The data on climate have generally been derived for 30-year periods. In most cases they relate to the period 1931-60, but in a number of cases (notably in Italy) other periods have been used. In many instances, too, the meteorological data for these periods were themselves incomplete (most especially due to interruptions by the war). As a result of these problems, minor discrepancies undoubtedly exist in the data, which may marginally affect calculations based on them.

More crucially, the distribution of the climatic stations for which data were available is uneven and in some areas (e.g. Greece) insufficiently dense. The climatic stations show a bias towards lowland, especially coastal, sites; upland areas are relatively under-represented. Regionalization of the climatic indices has been carried out using Thiessen polygons. Whilst these provide an adequate basis for defining climatic regions in lowland, relatively flat areas, with a dense network of stations, they are less satisfactory in mountainous or hilly terrain where abrupt local variations in climate occur, or in areas where the network of stations is sparse.

## 5.2.2. Soil

Data on soil properties have been derived mainly from the 1: I million soil map of the European Communities. Whilst this has the undoubted advantage of being based on a consistent classification, it nevertheless has a number of limitations. Chief among these are its scale. The average soil map unit is over 175 km² : as such, it clearly provides only the most general indication of soil pattern. The boundaries of these map units are also of doubtful validity: within each unit a considerable variation in soil conditions inevitably occurs. Estimates of average soil conditions (e.g. soil texture, soil depth) are consequently no more than order-of-magnitude values. They cannot be interpreted as either precise or generally valid descriptions. Nor are the soil boundaries depicted by the map any more than conceptual abstractions. They do not, of course, represent the sharp and regular boundaries which cartographically they imply; rather they define broad zones of transition, at best, or - more commonly - convenient yet essentially arbitrary divisions within a natural continuum.

In this context, too, it is important to appreciate that the descriptors provided by the soil map legend are themselves often highly generalized. Only two classes of stoniness, for example, can be defined (greater than, or less than, 10%). Information on salinity is equally broad. In many cases (and most especially Greece where a new soil map was compiled) these problems of data quality have meant that other, national information sources have also been used. The degree of consistency between these is unknown. Much of the information used in the analysis is also derived from the subjective interpretation of the soil maps. Despite the use of strict guidelines for interpretation, this, too, is likely to have introduced a number of inconsistencies.

## 5.2.3. Topography

lt has been noted that data on slope angle have been derived from a number of sources: DTMs (using different raw databases) in Spain and Portugal, and manual map analysis (using maps of different detail and scale) in the other countries. Apart from the inconsistencies which may exist between these methods, other problems also occur. A significant, though unknown, error is involved in all these analyses. This is due largely to inaccuracies in the height determinations (quoted as 20 to 100 metres), and insufficient sample points in the case of the DTMs. lt is also due to inaccuracies in the map base, operator and encoding errors, and limitations of the basic slope model in the case of manual map analyses. lt should nevertheless be noted that these data are spatially relatively detailed (with a resolution of I $km^2$) compared to other data used in the project.

## 5.2.4. Land cover

With the exception of Portugal where data derived from the CORINE land cover project were used, information on land quality is similarly of limited quality. Map sources were typically generalized, and often somewhat out of date. Only two classes of vegetation cover could be determined, and the distribution of these is inevitably highly generalized.

For Portugal, the availability of more detailed (1:100 000 scale) data on land cover from the CORINE land cover project was clearly an advantage. In the future, this source of data will be more widely available, and will undoubtedly improve the analysis. For the present, however, the use of different sources of data in different Member States introduces a significant degree of inconsistency.

## 5.2.5. Land improvements

As has been mentioned earlier, data on land improvements were extremely scarce, and undoubtedly inconsistent from one Member State (and probably one region) to another. Only land subject to permanent irrigation could he distinguished, and even this is only valid in general terms. Until better information is available, this data-set thus remains relatively poor.

## 5.2.6. Assessments of soil erosion risk and land quality

Given the numerous problems recognized in the raw data, it is apparent that similar caveats must be stated regarding the assessments of soil erosion risk and land quality derived therefrom. Inevitably, aggregation of uncertain data produces uncertain results. To a large extent, however, this uncertainty has been allowed for by the recognition of only 4 classes of soil erosion risk or land quality. The results therefore are intended to show no more than the general patterns, and at this level of analysis would seem to be broadly reliable and correct. Nevertheless, it is vital that anyone using the results appreciates their limitations and does not attempt to go beyond them (e.g. by interpolating between classes).

lt should also be noted that the aggregation methods used in this analysis were knowingly simple. The justification for this has been presented: given the data available and the constraints of time and resources, other, more sophisticated procedures could not be used. The approach, however, clearly makes no allowance for the complex and dynamic interactions between the various determinants of soil crosion risk or land quality. Assumptions have also had to be made about the relationships of these phenomena to the individual variables (e.g. soil texture, aridity, slope angle). Each of these assumptions, though defensible in general terms, can be challenged at the detailed level. The model is admitted to be a preliminary one, the results are explicitly a first approximation. They provide only a qualitative assessment of soil erosion risk; more detailed quantitative assessments must await the availability of better data. These provisos must be borne in mind when the data are used.

# 6. Lessons learned

The results provided by this project go a long way towards meeting the information needs of policy on land resources at the Community level. They are, however, only a first approximation: as more data become available and as assessment methods are refined, they can be improved. In the years ahead, new problems relating to soil conservation and land resource management will also inevitably arise. This will require further data collection and analysis. In the future, therefore, similar projects will be necessary to extend, update and improve the information which currently exists. Clearly these projects can benefit from the experience gained, and the lessons learned, in this present project.

## 6.1 Coordination

## 6.2. Scientific aspects

## 6.1 Coordination

### 6.1.1. International collaboration

### 6.1.2. Project organization

## 6.1.1. International collaboration

Amongst the most important of these lessons are those of coordination. Like other areas of Community interest, policy on land resources involves many different agencies operating at every level from the local to the international. At the international scale it involves not only the European Community but several other established organizations such as FAO, the Council of Europe and UNEP. Within the EC, it involves several different Directorates-General including those for the environment (DG XI), agriculture (DG VI) and statistics (Eurostat). To define policy needs, and to ensure that work builds upon - rather than duplicates - the activities of these organizations, requires close cooperation and consultation. This itself may take time. Because of the slightly different interests and agendas of these various parties, it also creates somewhat divergent and contradictory objectives: information needs tend to refer to different geographic areas and scales; the timescale for data collection may differ; the required levels of sophistication and accuracy may vary. Collaboration between these agencies does not therefore necessarily eliminate the contradictions, but it is essential to highlight them, and to minimize the risks of duplication of effort. Within CORINE a large effort was made to ensure that all the relevant institutions were involved in the preparation and implementation of the project. This experience showed, nevertheless, that coordination and convergence are not achieved once and for all but need to be worked at and continually maintained. Future projects will have to integrate this into their programmes as an important task.

## 6.1.2. Project organization

Collaboration is also essential at a more detailed level. As this project has shown, the study of issues such as soil erosion and land quality involves scientists from many different specialisms: soil scientists, agriculturalists, climatologists, ecologists, geographers, cartographers and computer scientists. These scientists need to be able to come together in a clear framework of mutual understanding.

They must agree unambiguously about the aims of the exercise and must understand the practical constraints upon it. They must understand, equally, the limitations of the data which each specialism provides. Above all, they must agree upon the analytical methods to be used, and apply them consistently.

As the experience of this project has shown, none of this is easy. Misunderstandings inevitably occur. Agreements reached at meetings may not be universally understood: subtleties of terminology or the obscurities of national language may create ambiguity. Once away from the meeting, and back in their own institute, the scientists involved find themselves under conflicting pressures: the mores and paradigms of their own specialisms, the realities of their own data sources, the strength of their own interests tend to pull them away. All too easily, therefore, the methods adopted tend to shift and diverge. Unless checked, the consequence is that inconsistencies begin to arise.

Despite the attempt to establish rigorous organizational procedures, all these problems occurred at intervals during this project. Discrepancies developed, for example, in the ways in which the algorithms for calculating soil erodibility and erosivity were applied. At times, disparities arose in the choice of variables, the aggregation methods and the means of data transfer. As far as can be determined, these inconsistencies have all been discovered and corrected, either through routine checks on data quality or during subsequent integration and analysis. Nevertheless, correcting them can prove to be a time-consuming process, and many weeks of work may have been wasted in the meantime.

From this experience, two specific lessons may be learned. The first is the need for careful quality control. In this project most of the data passed through a coordinating team, with responsibility for checking data consistency and completeness. Although this process did not reveal all the errors and discrepancies, it did allow many of them to be intercepted. Future projects would be well advised not merely to adopt this procedure, but also to strengthen it - for example, by allowing more time for data checking and carrying out more rigorous tests on the data provided. Statistical tests (e.g. comparing means and standard deviations from different data-sets, identification of extreme values, checking of zero and missing entries) are especially effective. Even more important, it may be noted, is mapping and trial analyses of the data at this stage; more than any other procedure this tends to reveal errors in the data, whilst at the same time providing a general check on the analytical approach.

The second lesson concerns the supervision and organization of the project team. Regular meetings to review progress may seem costly but are essential. These same meetings can also be used to check that the methods are being adhered to, and to ensure that any deviations are brought under control. In addition, of course, they allow refinements to be discussed and - if agreed - to be universally adopted. The experience of this project, however, has shown that more than this is required.

Working procedures must be clearly spelled out in writing, so that individual scientists can remind themselves of the agreed methods when necessary. A manual defining both the variables to be used and the analytical methods is therefore vital. This should be amended and recirculated when appropriate. Each new version should be clearly identified (e.g. with version number and date) and any alterations from previous versions highlighted. Last but not least, the project supervisor needs to carry out regular site visits to monitor the progress of the work, and check on consistency of application.

These structures may appear unnecessarily bureaucratic or merely obvious, according to one's experience and point-of-view. Their importance, however, can hardly be overemphasized. As has been said, errors or discrepancies in working practice inevitably affect the results. Checking and correction after the event is costly, and can seriously delay the project.

Allowance therefore needs to be made in the project planning for this process of coordination. While this may appear to increase the time and effort spent in the early phases of the project, it will undoubtedly be repaid by savings elsewhere. It will, moreover, greatly increase the credibility and reliability of the results.

## 6.2. Scientific aspects

## 6.2.1. Data availability and quality

In addition to these essentially management lessons, this project has shown a number of scientific lessons. One of the most fundamental concerns data availability. This is, in some ways, a contradictory lesson. On the one hand, it has indicated that far more data on land resources are often available than normally assumed. On the other hand, the major problems concern access and quality. Some of the most important data sources could not be used in this project because of constraints of cost or confidentiality: DTMs in France are an example. Other data - such as climatic information in France and Greece - were dispersed in a range of different sources, and could only be obtained at the expense of considerable effort.

More crucially, in many cases, the data which do exist are often of variable quality. Identifying and resolving the errors and inconsistencies they contain is thus a vital but time-consuming task. This is not only true of national data-sets, such as climatic data or topographic maps, but also of some international data-sets, such as the soil map of the European Community. The difficulties encountered in integrating this last example into the CORINE information system (e.g. Briggs et al., 1989) show the importance of these problems, and their potential cost to project development. They also indicate the immense investment which may be required to compile more detailed data in a consistent form. The lesson here is clear. Frequently, detailed data are available. They exist, however, in disparate sources and structures and can only be brought together in a usable form at the expense of prolonged and costly analysis. In a project such as this, the time and resources necessary for such work simply do not exist.

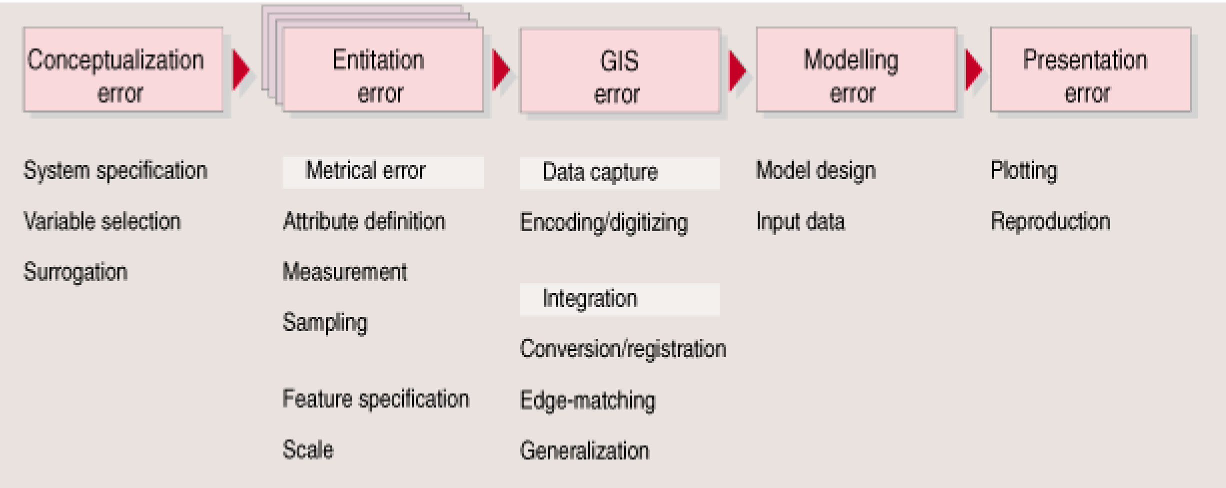
Two conclusions may be derived. The first is that a need exists for the long-term compilation and harmonization of basic data in the Community, to provide a basis for improved studies in the future. Such work must proceed independently of individual, short-term policy-related projects. The second conclusion is that, in the short-term, analysis is at the mercy of the data available.

This latter point should be stressed. In the project carried out here, it was apparent that a strong research base existed in relation to both soil erosion and land quality. Many theoretical and empirical models have been developed. These, however, are invariably data demanding. The constraint upon the level of sophistication in this project, therefore, was not any weakness in conceptual understanding nor in the availability of analytical methods. Rather, it was the lack of suitable input data. For this reason, the results presented here are seen only as a first approximation. For the same reason, the situation will only be improved when better basic data are available.

## 6.2.2. Reporting data quality

The presence of error and inconsistency in the data available also generates the need to understand the nature of data quality. Error may arise from many different sources, not only at the stage of initial measurement or survey, but also at later stages of data capture, analysis and reporting (Figure 6.1). Not all these errors and discrepancies will be identified and removed; many remain unknown, especially where the products of one study become used as the inputs to the next. (Again, the example of the EC soil map provides a clear example.) Users of the results must therefore be aware of the possibility of error in the data, and should have some understanding of how it might arise and its potential implications. In particular, it should be noted that the quality of the data may vary within any data-set, or even within a single feature (e.g. along a soil boundary). Like other projects in the CORINE programme, this project has highlighted the importance of properly documenting the full history of any data-set. It also indicates the need for methods of tagging data within any database according to its quality. To date, however, satisfactory procedures for data tagging have not been developed.

Figure 6.1 - Sources of error in data processing and analysis



### 6.2.3. GIS techniques

In bringing together, overlaying and analysing data on soil erosion risk and land quality in this project, much has been learned about the GIS techniques involved. Amongst other things, the experience has highlighted the importance and difficulties of registering data from widely different sources to the same geographic base.

Considerable effort had to be expended with both the soil coverage and the slope data in projection conversion, rubber-sheeting, edge-matching and final registration. The process was compounded by two circumstances: the inherent errors and inaccuracies in the digital coastline used for the geographic base (derived from the ONC maps); and the large data volumes involved. The differing qualities of the various data-sets also meant that these processes had to be closely supervised and could not be carried out entirely automatically.

Similar difficulties were encountered in the overlay and aggregation procedures. Here, comparisons were carried out using both vector-based and raster-based methods. In general, the raster-based approach proved to be most appropriate though the large data volumes again made the process demanding on system resources (hard-disk capacity, computer processing time). The raster approach also generated a considerable amount of background 'noise' in the results, partly as a result of combining data-sets of different resolution. This noise needed to be filtered out.

Although the procedures were slow and highly demanding of processing time, it may nevertheless be noted that the ARC/INFO software proved adequate for the task. There was nothing in this experience, therefore, to suggest that this software would not be appropriate for general use.  On the other hand, the exercise did stress the importance of having access to complementary computers with specific functions.

Finally, it may be mentioned that this exercise represents one of the most rigorous and demanding applications of GIS methods yet undertaken. The experience gained has far-reaching significance for anyone carrying out similar, broadscale analyses.

# 7. Needs for future development and research

As the foregoing discussion has indicated, the results of this project are neither definitive nor the final word regarding the assessment of soil erosion risk and land quality in the Mediterranean region. Much can still be done to extend the data and improve the methodology. This section outlines some of the specific aspects of the assessment methodologies that could usefully be improved, and indicates the needs for further analysis and research.

## 7.1. Data quality and availability

## 7.2 The assessment methodologies

## 7.1. Data quality and availability

Without doubt, problems of data availability and quality have posed some of the major constraints on the project undertaken here. Indeed, largely because of these problems, relatively simple models of soil erosion risk and land quality had to be used.

### 7.1.1 Climate

### 7.1.2. Soils

### 7.1.3 Topography

### 7.1.4. Land cover and land improvements

## 7.1.1. Climate

Some of the major limitations relate to data on climate. There is clearly a need for more detailed, comprehensive and consistent data throughout the region. Especially in the analysis of soil erosion risk, there is also a need to move from the use of general climatic parameters to more detailed and dynamic indices which take account of the short-term effects and stochastic nature of climatic events. Erosivity, for example, needs to be determined on the basis of precipitation intensity and frequency as opposed to the Fournier index and Bagnouls-Gaussen aridity index, calculated from 30-year monthly norms. Climatic quality could be more realistically modelled on the basis of integrated energy and moisture factors, such as actual evapotranspiration or accumulated soil moisture stress.

Equally, there is the need to apply more realistic and sensitive methods of regionalization, which take account of local topographic factors and climatic variation. The methods of tesselation used in this study are clearly over-simplistic and highly generalized. Opportunity exists to replace them by spatial modelling procedures such as splining (e.g. Hutchinson and Bishof, 1983), which take account of the relationship between climate and altitude.

## 7.1.2. Soils

The limitations which have been noted in the data on soils are largely inherent in the soil map of the European Communities, which was used as the primary source. Map units defined on this map are broad associations, comprising a dominant soil class and a range of other, secondary and associated soil types. Although the relative frequency and general character of each of these soil types is known, their geographical distribution within each mapping unit is not. The range of descriptive information available for each soil class is also limited. As a consequence, the map units provide only a broad and aggregate picture of soil conditions which disguises more local variation.

To improve the soil data, therefore, one of two developments needs to occur. One option is that the existing soil map needs to be revised, by the collection of detailed, geo-referenced data on soil profiles and site conditions throughout the Community, thereby allowing more detailed interpretations of map units to be carried out. The alternative is that the soil map should be recompiled from original information, at a more detailed scale (e.g. 1:250 000), and using a more comprehensive set of soil properties in order to derive soil mapping units which provide a better basis for the regional assessment of soil erosion risk and land quality.

With an improvement in the available data in these ways, more detailed and realistic estimates of soil erodibility and soil quality could be made. These would allow the application of more sophisticated assessments of soil erosion risk and land quality. They would also, of course, provide a more detailed input to other models and applications.

### 7.1.3. Topography

As has been noted, the acquisition of data on slope angle represented a particular problem in this project, and one which was overcome only by the use of a variety of sources and methods. All the methods used undoubtedly have limitations of accuracy and reliability, which limit the quality of the data obtained.

Significant inconsistencies also no doubt occur between results for different areas. To improve this situation is not easy. The most effective approach, however, is likely to be through the use of digital terrain models (DTMs) similar to that applied in Spain. Such models already exist for France and are likely to become available for other areas in the years ahead.

## 7.1.4. Land cover and land improvements

The improvement of data on land cover is perhaps one of the most urgent requirements for future work especially in relation to soil erosion risk. Fortunately, the scope to do so exists through development of the CORINE land cover project. Extension of this project to the remainder of the Community will undoubtedly permit much-improved assessments of soil erosion risk. This project will likewise offer the opportunity to improve data on land improvements such as terracing and irrigation, thereby improving assessments of land quality.

## 7.2. The assessment methodologies

### 7.2.1. Soil erosion risk

### 7.2.2. Land quality

## 7.2.1. Soil erosion risk

It was admitted at the outset of this report that the methods used to assess soil erosion risk were relatively simplistic and crude. The reason for this was not so much the limited understanding of the soil erosion system, as the lack of data and the constraints of time and resources available to the project. lt would have required much more both in terms of research time and costs to develop and apply a more rigorous quantitative model. And even this could not have guaranteed more reliable or accurate results. It would clearly have been inappropriate to wait until such methods could be developed and used, for by then many of the problems of soil erosion in the Community would have grown much worse.

Nevertheless, it is apparent that future development of this work would allow more sophisticated models of soil erosion to be used. This may be achieved in the first place by development and improvement of the assessment method used here. In this case, particular attention needs to be placed on improving the factors used in the procedure, notably in the calculation of erosivity and soil erodibility, and in the classification of land cover. As noted above, for example, erosivity could better be derived on the basis of measures of rainfall intensity and frequency. Similarly, the assessment of soil erodibility might include more explicit factors such as soil organic matter content, carbonate content and permeability. The relationship of stoniness to soil erodibility also needs to be investigated, so that its effect can be more realistically included in the model. Land cover, likewise, needs to be classified more finely, on the basis of the protection it affords the soil.

The aggregation procedures used in the existing model might equally be improved. At present, aggregation involves a relatively simple process of scoring, weighting and combining the various indices in a hierarchical fashion. Though this is a convenient and open procedure, allowing careful control of the aggregation process, it does not simulate the real structure of the erosion system. More realistic methods of aggregation need to be based on an explicit structural model of this system.

As this indicates, the ultimate need is clearly to progress to a more realistic soil erosion model. This might be based more closely on the universal soil loss equation of Wischmeier et al. (1971) or any of the other quantitative models developed in recent years.

More rigorous models of this sort would certainly provide the opportunity for more detailed and reliable assessments of soil erosion risk. To achieve this, however, it will first be necessary to carry out a careful comparison and evaluation of the various models (e.g. on the basis of pilot studies in representative areas) and to improve greatly the quality of the input data. Further fundamental research therefore needs to be done. In the meantime, undoubtedly, the existing data are a valuable information source on soil erosion risk, and can play a significant role in policy formulation.

## 7.2.2. Land quality

Similar comments may be made regarding the assessment of land quality. Here, too, it is clear that the assessment method can be improved by refining the input variables and developing better procedures for aggregation. An especial need in this case is for improved methods for assessing climatic quality, taking account perhaps of the relationship between temperature, rainfall and evapotranspiration. Various procedures for modelling these relationships are available (e.g. Baler, 1973; Briggs, 1983; de Wit and van Keulen, 1987). Aggregation procedures also might be improved, by applying models which relate more closely to the structure of the plant growth system (e.g. de Wit and van Keulen, 1987; Centre for World Food Studies, 1980). Again, however, such developments can only be achieved on the basis of detailed research to devise and compare appropriate models, and the acquisition of more detailed and comprehensive data.

The results of this exercise are thus a vital contribution to policy in the European Community, and can be used to help protect key land resources. Nevertheless, they are not the end of the story. In the future, they will need to be refined, extended and updated to improve these policies and to adapt to new problems as they arise. The experience of this project shows the way forward. The land is a vital and irreplaceable resource: continued efforts to provide the information necessary to protect this resource are therefore clearly worthwhile.

# List of contributors

| Name | Organization | Country |
|---|---|---|
| **Project leader:** | | |
| Professor Andrea Giordano | Soil expert - Aquater Spa San Lorenzo in Campo (1)<br>Università di Torino (since 1987)<br>Istituto idraulica agraria<br>Corso Raffaello 8<br>10126 Turin | Italy |
| **National teams:** | | |
| Professor Andrea Giordano | Università di Torino<br>Istituto idraulica agraria<br>Corso Raffaello 8<br>10126 Turin | Italy |
| F. Cassi<br>C. Marchisio<br>P. Martens | Edafos SpA<br>Via di S. Spririto, I<br>50125 Florence | Italy |
| Professor Paul Bonfils | Les jardins d'OC bat. A<br>9 ter av. de la Gaillarde<br>34000 Montpellier | France |
| J.P. Barthes<br>M. Bornand<br>J. Wilbert | Institut nat. de la recherche agronomique,<br>Place Viala<br>34060 Montpellier | France |
| P. Favreau | Off. dév. agricole région Corse | France |
| R.E. Quelennec<br>C. Oliveros | Bureau de recherches géologiques et minières<br>Domaine de Luminy<br>13009 Marseilles | France |
| Professor Carlos Roquero | c/Bolonia 4-1<br>28028 Madrid | Spain |
| M. Magister | Escuela Superior Agronomia<br>Universidad de Madrid<br>Madrid | Spain |
| Professor Nicolas Yassoglou | Vrilision 20<br>15236 Old Pendeli - Attica | Greece |
| Dr C. Kosmas | Laboratory of Soils<br>Faculty of Agronomy<br>Athens | Greece |
| Dr Eugenio Sequeira<br>Dr M. Pereira Gomes | Estaçaó Agronómica Nacional<br>2780 Oeiras | Portugal |
| J.Casimiro Martins<br>M. Conçe | | |
| **Scientific coordinator:** | | |
| Professor David J. Briggs | Department of Geographical and | United Kingdom |

Environmental Sciences
Huddersfield Polytechnic
Queensgate
Huddersfield HD1 3DH

**Project management:**

| | | |
|---|---|---|
| Michel-Henri Cornaert | CEC, DG Xl Task Force | Belgium |
| Denis Peter | CORINE programme<br>rue de la Loi, 200<br>1049 Brussels | |

**Slopes:**

| | | |
|---|---|---|
| Professor I.B.F. Kormoss | Korte Winkel 9<br>8000 Bruges | Belgium |
| S.Mas | Instituto Geografico National<br>General Ibanez Ibero, 3<br>28071 Madrid | Spain |
| A. Castelo Branco | Direcçao G. da Qualidade do Ambiente<br>Rua de Secolo, 51<br>1200 Lisbon | Portugal |

**Data quality control:**

| | | |
|---|---|---|
| Elaine Kerrell<br>Catherine Fierens<br>Araya Redda | Whimbrel Consultants/Huddersfield<br>Polytechnic, Queensgate<br>Huddersfield HD1 3DH | United Kingdom |

**Computing and database construction:**

| | | |
|---|---|---|
| Dr Helen Mounsey<br>Paul Brignall<br>Teresa Conolly<br>Ann Wilkes | Birkbeck College<br>7-15 Gresse Street<br>London Wl P IPA | United Kingdom |

**Computer overlay, analysis and integration:**

| | | |
|---|---|---|
| Jef Maes<br>Wim Devos | CEC,DGXI Task Force<br>CORINE programme<br>rue de la Loi, 200<br>1049 Brussels | Belgium |

**Acknowledgements (Photographs and illustration)**

| | |
|---|---|
| Page 1 | Greece (Peloponnisos) A. Nychas |
| Page 10 | Greece (Peloponnisos) A. Nychas |
| Page 18 | Italy (Calabria - Cropalati) A. Giordano |
| Page 22 | Spain (Castilla La Mancha) C. Roquero |
| Page 30 | Spain (Andalucia) J.M. Moreira |
| Page 36 | France (Hérault) P. Bonfils |
| Page 39 | Italy (Marche - Montemaggiore) A. Giordano |
| Page 40 | Italy (Toscana - Firenze) D. Peter |
| Page 60 | Spain (Andalucia) J.M. Moreira |
| Page 66 | Portugal (Alentejano) E. Sequeira |
| Page 69 | France (Bouches du Rhône) R. Dannau |
| Page 70 | France (Hérault - Lodève) P. Bonfils |
| Page 82 | Italy (Appennino pistoiese) Vasari (Archivi Alinari) |
| Page 88 | Spain (Castilla La Nueva) C. Roquero |

# References

Aquater SpA. 'Carta della geologia e dei dissesti', in *Carta della montagna,* Rome, Ministero dell'agricoltura e foreste di concerto con il Ministero dei lavori pubblici, 1977.

Baier, W. 'Crop/weather analysis model: review and model development', *Journal of Applied Meteorology* 12, 1973, pp. 937-947.

Bergsma, E. 'Method of a reconnaissance survey of erosion hazards near Merida, Spain', *Proceedings of the Workshop on Assessment of Erosion, Faculty of Agricultural Sciences, Ghent, 27 February to 3 March 1978,* Chichester, John Wiley and Sons, 1980.

Bermúdez, F.L. and Escudero, J.D.G.'Estimación de la erosión y aterremientos de embalses en la cuenca hidrográfica del río Segura', in *Cuadernos de investigación,* Tomo VIII, Faseículos 1 and 2, Logroño, Colegio Universitanio de la Rioja, 1982.

Biagi, B. 'Development of a database of land characteristics and computerized analysis of actual and potential land degradation risks', in *Soil erosion in the European Community,* G. Chisci and R.P.C. Morgan (eds), Rotterdam, Balliema, 1986.

Briggs, D.J. *Biomass potential of the European Community - A report of a case study to develop a bioclimatic method of assessing the potential forbiomass production,* Sheffield, University of Sheffield, 1983.

Briggs, D.J. and Coleman, R. 'Effects of changes in atmospheric C02 concentrations on biomass potential and runoff potential in the European Community', unpublished consultancy report to Dornier Systems GmbH, 1984.

Briggs, D.J., Brignall, P. and Wilkes, A. 'Assessing soil erosion risk in the Mediterranean region: the Corine programme of the European Communities', in *Application of computerized EC soil map and climate data - Proceedings of a workshop in the Community programme for coordination of agricultural research, Wageningen, 15 and 16 November 1988,* H.A.J. van Lanen and A.K. Breght (eds), Luxembourg, Office for Official Publications of the European Communities, 1989, pp. 195-210.

Caderville-Levy, G. and Vogt, H. 'Carte de 1'érosion hydrique potentielle des sols en France', in *Atlas de la France,* Paris, Reclus, in press.

Centre for World Food Studies. *The model of physical crop production,* Wageningen, Centre for World Food Studies research report SOW-80-5, 1980.

Centro Nacional de Reconhecimento e Ordenamento Agrário, several soil maps, various years.

Commission of the European Communities (1985a). *Soil map of the European Communities, 1:1* million, Luxembourg, Office for Official Publications of the European Communities, 1985.

Commission of the European Communities (1985b). *Official Journal of the European Communities,* L 176, 6.7.1985.

Commission of the European Communities (1 990a). *Official Journal of the European Communities,* L 81, 28.3.1990.

Commission of the European Communities (1 990b). *Official Journal of the European Communities,* L 120, 11.5.1990.

de Wit, C.T. and van Keulen, H. 'Modelling production of field crops and its requirements', *Geoderma* 40, 1987, pp. 253-265.

Dirección General de la Producción Agraria. *Mapa de cultivos y aprovechamientos,* Madrid, Servicio de Publicaciones Mapa, various years.

Duclos, G. 'Appréciation de l'aptitude à la mise en valeur forestière et agricole des zones accidentées de Provence', *Forêt méditerranéenne Vol.* 11, No 1, 1980.

FAO. 'A framework for land evaluation', *FAO soils bulletin* No32, Rome, 1976.

Finlayson, B. and Statham, I. *Hillslope analysis,* London, Butterworths, 1980.

Fournier, F. *Climat et érosion,* Paris, Presses universitaires de France, 1960.

France, J., Brockington, N.R. and Newton, J.E. 'Modelling grazed grassland systems: wether sheep grazing perennial ryegrass'. *Applied Geography 1,* 198 1, pp. 133-150.

References

Gazzolo, T. and Bassi, G. 'Carta delle isolinee di ugual erosione in Italia', in *Contributo allo studio del grado di erodibilità dei terreni costituenti i bacini montani dei corsi d'acqua in Italia,* Memorie e studi idrografici, Rome, Ministero dei lavori pubblici, Servizio idrografico, pubblic. 2, Vol. IV, 1966.

Giordano, A. 'Guidelines for soil erosion risk', working paper, San Lorenzo in Campo, Aquater, 1987.

Graziani, C.A. 'Erosione dei suoli agricoli nella CEE', in *Ambiente, risorse e salute,* aprile 1988.

Hutchinson, M.F. and Bischof, R.J. 'A new method for estimating the spatial distribution of mean seasonal and annual rainfall applied to the Hunter valley, New South Wales', *Australian Meteorological Magazine* 31, 1983, pp. 179-184.

lcona. 'Paisajes erosivos en el Sureste Español', *Proyecto Lucdeme Monografías* 26, Madrid, Instituto Nacional para la Conservación de la Naturaleza, Ministerio de Agricultura, Pesea y Alimentacion, 1982.

*lcona. Mapas de estados erosivos,* Madrid, Instituto Nacional para la Conservación de la Naturaleza, Ministerio de Agricultura, Pesea y Alimentacion, 1988.

IPLA. *La capacitá d'uso dei suoli del Piemonte. Assesssorato alla pianificazione e assessorato all'agricoltura e foreste, Regione Piemonte,* 1982.

Kormoss, l.B.F. 'Cartes des pentes moyennes d'ltalie', *Informations internes sur l'agriculture* 143, Brussels, Commission of the European Communities, March 1975.

Lulli, L., Lorenzoni, P. and Arretini, A. 'Esempi di cartografia tematica, Prima sperimentazione per lo studio e la difesa del suolo e progetto finalizzato', CNR, Conservazione del suolo, unità operativa 14, pubblicazione n. 56, 1980.

Madueño, J.M. 'Degradacion, susceptibilidad y tolerancia a la erosión de los suelos de Andalucia', paper presented to Seminar on land evaluation in the Mediterranean environment, Seville, 17 to 19 September 1987.

Nakos, J., Mavromatis, G. and Jurdans, M. *Integrated land survey of the Evrytania region,* Athens, Greek Ministry of Agriculture, Forestry Service, 1980.

Quirantes, Puertas J. 'Erosión eólica. Valoración experimental' Universidad de Murcia, *Papeles de Geografia Fisica 12,* 1987.

Regione Emilia-Romagna. *Carta della stabilità dei versanti,* various sheets, scale 1:25 000, progetto finalizzato, Conservazione del suolo, 1980.

Rodolfi,G. 'Criteri di conservazione del suolo per l'incremento della produttività agricola nelle aree marginali appenniniche desunti da un'analisi pedo-geomorfologica di dettaglio', nota preliminare (con esemplicificazione cartografica), in *Annali dell'Istituto sperimentale di studio e difesa del suolo* (Firenze), Vol. 17, 1986.

Shahabi, S. *The soils of Drama, with special reference to the soils of Drama Basin,* Institute for Chemistry and Agriculture, Piraeus, N. Kanellopoulos, 1982.

Stewart, D. and Dwyer, L.M. 'Development of a growth model for maize', *Canadian Joumal of Plant Science* 66, 1986, pp. 267-280.

Ufficio analisi e ricerche territoriali. *Capacita duso dei suoli della Regione Emilia-Romagna,* Servizio coordinamento, programimazione c pianificazione Regione Emilia-Romagna, 1981.

Williams, J.R., Jones, C.A., Kiniry, J.R. and Spanel, D.A. *The EPIC crop growth model,* transactions of the American Society of Agricultural Engineers, 1989.

Wischmeier, W.H. 'Use and misuse of the universal soil loss equation', *Joumal of Soil and Water Conservation* 31, 1976, pp. 5-9.

Wischmeier, W.H. and Smith, D.D. 'Predicting rainfall-erosion losses from cropland east of the Rocky mountains', *USDA Agricultural Handbook* 282, Washington DC, 1965.

Wischmeier, W.H., Johnson, C.B. and Cross, B.V. 'A soil erodibility nomograph for farmland and construction sites', *Joumal of Soil and Water Conservation* 26, 1971.

Yassoglou, N., Apostolakis, C., Nobeli, C. and Vrachamis, C. *A study of the soil of Messara valley in Crete, Greece,* Athens, Greek Nuclear Research Centre, Department of Earth Sciences, 1971.

References

Yassoglou, N., Nychas, A., Apostolakis, G. and Kosmas, C. *Soil survey report of Argos plain,* Larissa, Ministry of Agriculture, Soil Survey Institute, 1983.