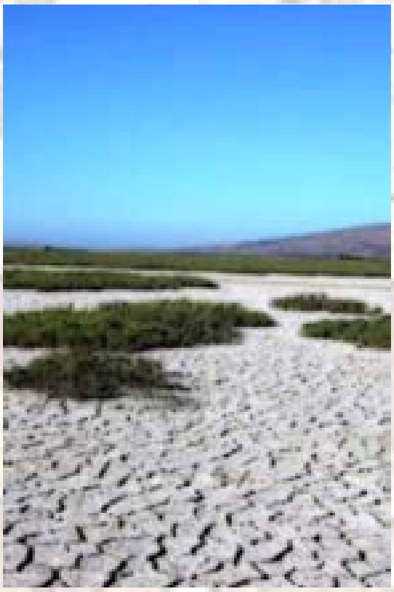
DESIRE REPORT series



Description of indicators defined in the various study sites

WB2: Land Degradation Indicators

Compiled by: Agricultural University of Athens

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Contents

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1. Introduction

A plethora of international and national organizations have recognized that environmental and socio-economic indicators are playing an increasingly important role in supporting development policies for combating desertification. The necessity of elaborating indicators is one of the priorities identified by the United Nations Convention to Combat Desertification (UNCCD). The Convention has recognize the need for using indicators as the appropriate tool to provide operational support to a wide range of activities such as assessing and mapping the extent of desertification, as well as determining the causes, quantifying the impacts, justifying expenditure for mitigation measures and monitoring the efficiency of the measures undertaken. Furthermore, the implementation of Ten Year Strategy Plan for Combating Desertification formulated in COP8 (Madrid, 2007) has adopted specific indicators for assessing the performance and the impacts for the implementation of the Convention outcomes. In this context, the necessity for identifying a series of indicators of desertification based on scientific criteria in order to guarantee a close and real relationship between the indicator and the state or trend that it represents is more than evident.

The identification, evaluation and the effective use of indicators requires a series of characteristics that have been proposed by various authors (Stein *et al.*, 2001). In 2001 the DESERTLINKS project was set up to assist the National Action Plans of the Annex IV countries with their indicator needs and this resulted in the state-of-the art DIS4ME indicator system that can be consulted on line by stakeholders. One core question about indicators is their feasibility and usefulness. The most appropriate indicator is not the one that provides the best information about the state and future trends for desertification, but the indicator that takes into account the available information and knowledge under low cost. For the identification and evaluation of indicators a series of characteristics have been proposed by various authors (Riley, 2001; Stein *et al*., 2001). The selected indicators have to be: (a) objectively and scientifically measurable, (b) preferentially quantitative, (c) easy and cost-effective to be measured, (d) sensitive to environmental changes, (e) simple in concept and accessible to both specialists and land managers, and (f) able to support policy decisions.

Several descriptions and definitions of the term “indicator” have been given by various agencies. The European Environmental Agency (EEA) has considered that an indicator can be defined as a parameter or value derived from parameters, which provides information about a phenomenon (OECD, 1993; EEA, 1998). In this essence, indicators should not be confused with raw data, from which they are derived. Indicators are quantified information which helps to explain how things are changing over time and space for decision making (EEA, 1998). Indicators generally simplify the reality in order to make complex phenomena quantifiable, so that information can be communicated (Department of Environment, UK, 1996; EEA, 1998). It should be point out that a complex process, such as soil erosion, can not be described using a single indicator but several indicators would be necessary, even if not many, but organized into a precise set. In particular, an environmental indicator is a parameter, which provides information about the situation or trends in the state of environment, in the human activities that affect or are affected by the environment, or about relationships among such variables (USA EPA, 1995; EEA, 1998).

A significant number of authors (O’ Connor, 1994; Pieri *et al.*, 1995; SCOPE, 1995; Dumanski & Pieri, 1996) considered that classification of indicators must take into account the linkages among; (a) pressures exerted on the environment by human activities, (b) changes in quality of the environmental components, and (c) societal responses to these changes that can be a useful and valuable tool for land-users and policy makers. In this sense, the DPSIR framework (Driving forces, Pressure, State, Impact, and Response) has been proposed (Fig. 1). In this scheme indicators can be briefly delineated as a chain reaction process starting from a developmental effort of natural resources, which applies Pressures and driving forces on the system, changing consequently the State of the system. Such a change produces Impacts, which leads to Responses that by a feed back loop interact with the Driving forces, the Pressures, the State and the Impacts. In this regard, the policy makers can have information for all the steps in the presented framework.

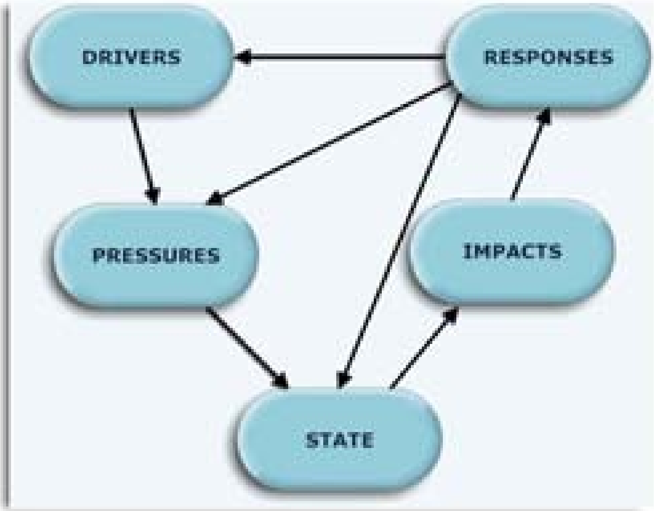

Fig. 1. DPSIR framework for system conditions used for classifying indicators (EEA, in Gentile, 1998).

In this context, **driving forces indicators** may delineate the economic, social and demographic conditions in a given time frame of a certain local. Such indicators also present the resulting changes in production, life styles and consumption. In this regard, the principal driving forces are population growth and the changes in economic and social modes. Such driving forces are creating the corresponding changes in consumption and production. Thus, according to the DPSIR chain these driving forces are applying pressure to the environment.

Pressure indicators usually express changes in the use of natural resources (water, land, minerals), biological and natural agents, emissions etc. Therefore, the pressures applied by the economic and social frame and practices to the physical system are resulting to the induced changes in the system elements.

State indicators demarcate the status of various parameters in a given local situation. They may present biological parameters (wildlife resources, etc.), chemical parameters (nitrogen, phosphorous concentrations in the soil or in water bodies etc.), or the quality and quantity of natural parameters (rain, temperature etc.).

Impacts indicators are describing the impacts provoked by the changes of the state of the system. Impacts are generated on resources availability, biodiversity, economic relationships, social functions etc. The impacts generate the willing of the people to face the problem by responding with certain measures.

Responses indicators are associated with and describe applied measures by societal groups or institutional organizations to confront, overcome, predict and prevent, compensate and adapt to the transformations of the state of the system. In addition responses indicators are delineating policy measures to preserve certain desirable system features.

In this project indicators have been considered in such a general framework and classified further to be easily used by the various stakeholders in the following categories: (a) physical and ecological environment including climate, soil, water, vegetation, water runoff, fires; (b) economics including agriculture, cultivation, husbandry, land management, land use, water use, tourism; (c) society; and (d) infrastructure. Finally, the objectives of this WP are to:

a) Define a practical number of indicators based on a shortlist of indicators available from literature, previous and ongoing research programs.

b) Document and develop a harmonized data base of indicators used or being used by different parties in the selected study areas by conducting field surveys on prevailing land use types affecting desertification in Mediterranean locales.
c) Compare and link indicators and land management practices among the various studied hot study sites.

The data of the indicators defined in each study site are presented in the deliverable 2.1.3 in excel form, while the detailed description of the various indicators applied in the various land use types in each study area is presented in the current deliverable.

All in all, in deliverable 2.1.3, data for the various indicators have been collected from the following 17 study sites located along the Mediterranean Europe, Eastern Europe, Africa, Asia, and Latin America, namely:

1. Rendina Basin Basilicata-Italy
2. Nestos Basin Maggana-Greece
3. Crete-Greece
4. Mação- Portugal
5. Gois - Portugal
6. Guadalentin Basin Murcia-Spain
7. Konya Karapinar plain-Turkey
8. Eskisehir Plain, Turkey
9. Novij Saratov-Russia
10. Djanybek-Russia
11. Zeuss Koutine-Tunisia
12. Boteti Area-Botswana
13. Santiago Island-Cape Verde
14. Mamora Sehoul-Morocco
15. Loess Plateau-China
16. Secano Interior-Chile
17. Cointzio catchment-Mexico.

In the following chapter a detailed analysis is undertaken of the identified in the study sites 72 indicators.

2. Indicators Description

2.1 Climate characteristics indicators

Climate is an important factor affecting plant growth, water availability, water demands, and land degradation. Climate, as it has been recognized by UNCCD, is an important factor affecting desertification. Arid, semi-arid, and dry sub-humid areas can potentially become desertified. Global climate change is expected to increase the vulnerability of the land to degradation in Mediterranean environments. The identified indicators related to climatic conditions that can create large water deficits and affect land degradation and desertification in the DESIRE project are: (A) air annual temperature, (b) annual rainfall, (c) aridity index, (d) annual potential evapotranspiration (ETo), (e) rainfall seasonality, and (f) rainfall erosivity.

Air temperature

Air temperature in combination with other climatic characteristics affects the xerothermic index and the vulnerability of an area for desertification. It is a critical environmental factor in determining water stress and transpiration of the growing vegetation as well as soil water evaporation and soil salinity and alkalinity. It is a critical factor affecting forest fires during the dry period in arid and semi-arid climatic conditions. Data on annual air temperature have been provided form the pertinent Meteorological Survives and for meteorological stations located in or nearby to the study sites areas. The following classes of air temperature (t) have been identified for the purpose of this project: (a) t<12 ^{o}C, (b) t changing from 12-15 ^{o}C, (c) t ranging from 15.1-18 ^{o}C, (d) t ranging from 18.1-21 ^{o}C, and (e) t >21 ^{o}C.

As Table 1 shows, air temperature has been defined in 446 questionnaires, corresponding to 8 study sites. This indicator was not filled in all the study sites, since it was identified as a candidate indicator affecting particularly areas sensitive to desertification due to soil salinization. Based on the available data for the above mentioned study sites, the average annual air temperature shows a wide range of values. As Fig. 2 shows, the dominant class of annual air temperature in the study field sites is less than 12 ^{o}C, covering 37.9% of the sites, and corresponding to all study field sites of Novij Saratov-Russia, and in several cases of Djanybek-Russia site. The next important class of air temperature defined is the range 15-18 ^{o}C, covering 30.7% of the study field sites, and corresponding to the study sites of Crete-Greece, Nestos-Greece, Cointzio catchment-Mexico, and Mação-Portugal. Annual air temperature ranging between 18-21 ^{o}C has been defined in 10.8% of the study field sites, corresponding to Crete-Greece study site. Annual air temperature >21 ^{o}C has been defined in 11.7% of the study field sites, corresponding to Boteti-Botswana, and Djanybek-Russia sites (Fig. 2). Finally, air temperature ranging between 12-15 ^{o}C has been found in 9% of the study field sites, corresponding to Cointzio catchment-Mexico, and Gois-Portugal study sites.

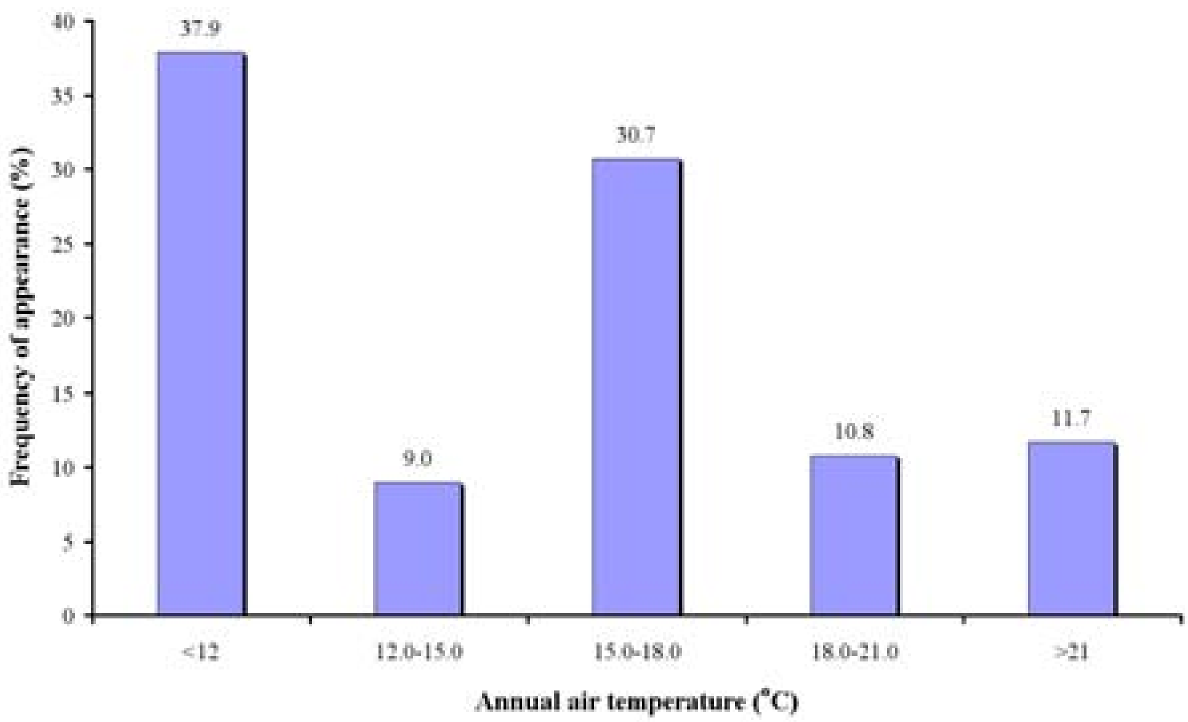

Fig. 2. Average annual air temperature classes prevailing in certain study field sites

Table 1. Number of field sites in which the indicators related to climate was recorded in the filled questionnaires

site no	Study site	Number of field sites described for the indicator					
		Air	Rainfall	Aridity	Pot.	Rainfall	Rainfall

		Temper.		index	Evapotran.	seasonality	Erosivity
1	**Rendina Basin, Basilicata, Italy**	-	30	-	-	-	-
2	**Secano Interior, Chile**	-	28	28	28	28	28
3	**Nestos Basin, Maggana, Greece**	30	30	30	30	30	-
4	**Loess Plateau, China**	-	150	-	-	-	-
5	**Gois, Portugal**	30	30	30	30	30	-
6	**Mação, Portugal**	31	31	31	31	31	-
7	**Boteti Area, Botswana**	23	59	56	56	56	28
8	**Eskisehir, Turkey**	-	70	70	70	70	70
9	**Konya, Karapinar plain, Turkey**	-	74	74	74	74	74
10	**Cointzio watershed-Mexico**	20	87	87	87	87	67
11	**Santiago Island, Cape Verde**	-	103	103	103	103	103
12	**Mamora/Sehoul, Morocco**	-	120	120	120	120	120
13	**Zeuss-Koutine, Tunisia**	-	120	120	120	120	120
14	**Guadalentin Basin, Murcia, Spain**	-	121	121	121	121	121
15	**Novij, Saratov, Russia**	100	122	122	122	122	22
16	**Djanybek, Russia**	98	138	138	138	138	40
17	**Crete, Greece**	114	269	269	269	269	155
	TOTAL	446	1582	1399	1399	1399	948

Annual rainfall

Rainfall, amount and distribution, is the major factor affecting biomass production, and also soil erosion rates on hilly lands. Arid, semi-arid, and dry-sub humid climatic conditions are characterized by seasonal climate and specific ecological conditions, which make the existing ecosystems vulnerable to land degradation and desertification. The uneven annual and interannual distribution of rainfall and the occurrence of extreme events are the main climatic factors contributing to land degradation. The prevailing weather conditions during the growing period of plants may be so adverse that the soils remain bare, creating favorable conditions for overland flow and erosion. Studies conducted during the execution of MEDALUS projects have shown that soil erosion in hilly areas of the Mediterranean region with shrubby vegetation increases as annual rainfall decreases from 650 mm to 300 mm. The increase in soil erosion is attributed to the decreasing biomass production accompanied with lower vegetation cover. The trend during the last decades in the study sites of DESIRE is a decrease in the annual rainfall and an increase in the number of stormy events. Also, predictions using models show that a climate warming is accompanied by lower amounts of rainfall and higher rates of evapotranspiration. Under such conditions soil moisture content available for plant growth will decrease significantly, causing lower biomass production, decrease in soil organic matter content, deterioration of soil aggregate stability, decrease in soil infiltration rates, and increase in soil erosion rates and in desertification risk (Fig. 3). Furthermore, the transport and distribution of salts within a landscape and in a soil profile are affected by the prevailing water balance conditions, and the depth of the ground water. A general decrease in precipitation and/or an increase in evapotranspiration will cause an increase of the areas affected by soil salinization, especially of the lowlands around the Mediterranean region. Soil salinity problems will be most severe in areas receiving annual rainfall ranging from 300-600 mm.

Fig. 3. Examples of areas receiving annual rainfall less than 300 mm (left, Cape Verde, Santiago islands) and greater than 750 mm (right, Peloponnesus, Greece)

Data for this indicator have been provided form the National and Local Meteorological Survives of the study sites and for meteorological stations located in or nearby to the study sites. The following classes of annual rainfall have been distinguished based on experimental data on soil erosion obtained from previous research and other pertinent research projects on desertification: (a) annual rainfall <280 mm, (b) annual rainfall 280-650 mm, (c) annual rainfall 650-1000 mm, and (d) annual rainfall >1000 mm.

As Table 1 shows, data on annual rainfall were collected in 1582 field sites, corresponding to 17 study sites. The majority of the study field sites (69.1% of the total field sites) have an annual rainfall ranging between 280-650 mm (Fig. 4). Such field sides have been found in all cases of the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Rendina Basin Basilicata-Italy, Nestos Basin Maggana-Greece, Guadalentin Basin Murcia-Spain, Eskisehir-Turkey, Konya Karapinar plain-Turkey, Loess Plateau- China, Mamora Sehoul-Morocco, and Crete-Greece, and in some cases in the study sites of Djanybek-Russia, Cape Verde-Santiago Island, and Crete-Greece. Therefore, such study field sites can be characterized as very sensitive to any climatic change and they are subjected to high vulnerability for land degradation and desertification. The next most important class of annual rainfall is the range of 650-100 mm, covering 15.1% of the study field sites, and corresponding in the study sites of Djanybek-Russia, Secano Interior-Chile, Mação-Portugal, Cointzio catchment-Mexico, and Crete-Greece. The driest field sites have been found in Zeuss-Koutine (Tunisia), in Santiago island (Cape Verde), and in Djanybek (Russia), covering 11.0% of the study sites. On the contrary, the wettest field sites are located in Gois-Portugal, and Cointzio catchment-Mexico study sites, covering 4.8% of the DESIRE field sites.

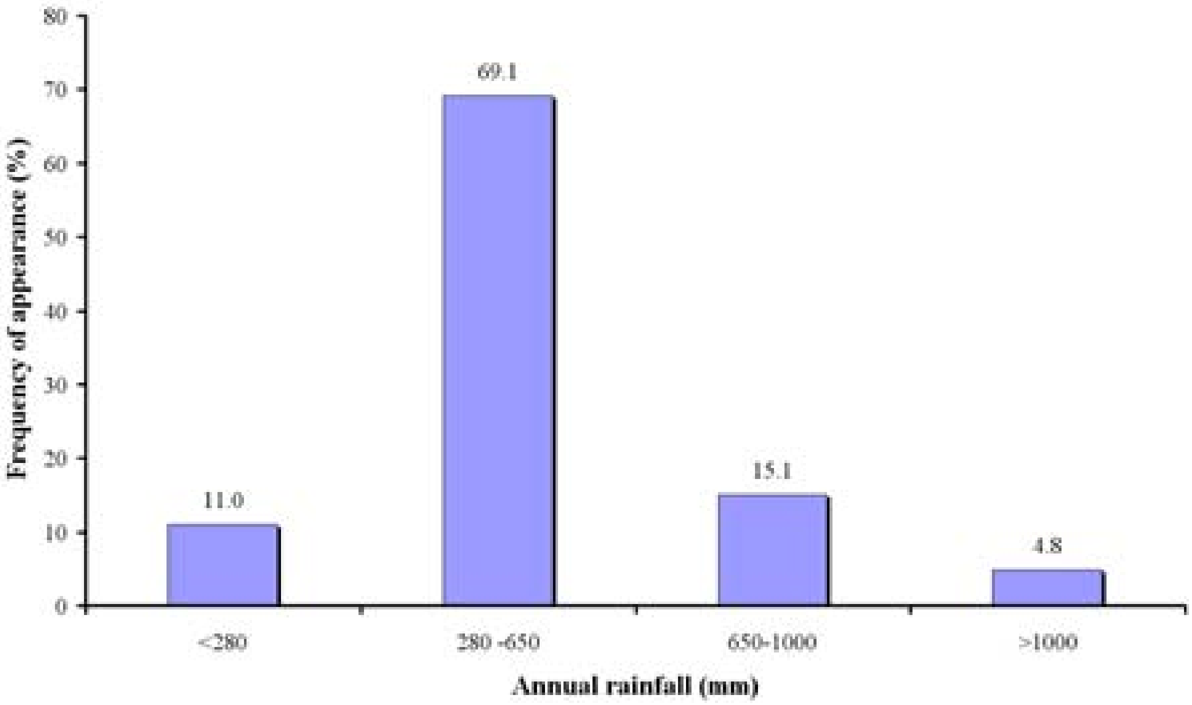

Fig. 4. Distribution of average annual rainfall classes prevailing in the study field sites

Aridity index

The aridity index classifies the type of climate in relation to water availability. The atmospheric conditions that characterize a desert climate are those that create large water deficits, in other words where potential evapotranspiration is much greater than the precipitation. The higher the aridity index of a region the greater the water resources variability and scarcity in time, the more vulnerable the area to desertification (Fig 5a). Soil loss and drought indices can be used to scale the state of health of soil and water resources and consequently to the formulation of strategies compatible with the resources available in a given area.

Aridity index in this study is defined as the ratio between mean annual precipitation (P) and mean annual evapotranspiration (ETo) using the Bagnouls-Gaussen index (BGI) from the following equation:

$$\sum_{i=1}^{n} \mathrm{BGI} = \sum_{i=1}^{n} (2ti - Pi)*k$$

Where: ti is the mean air temperature for month i in 0°C, Pi is the total precipitation for month i in mm; and k represents the proportion of month during which 2ti - Pi >0. The following classes have been distinguished for this indicator: (a) BGI<50, (b) BGI ranging from 50-75, (c) BGI ranging from 75-100, (d) BGI ranging from 100-125, (e) BGI ranging from 125=150, and (f) BGI>150.

Fig. 5a Severe drought (1999-2001) affected heavily the olive groves in the plain of Jeffara, Tunisia(left) and grazing land under arid climatic conditions in Crete (right)

Data for this indicator were calculated for 1339 field sites, corresponding to 15 study sites areas (Table 1). The analysis of the data has showed that a great variability in aridity index exists (Fig. 5b). The most important class of aridity index was 125-150, covering 26.7% of the study field sites, and corresponding to the study sites of Guadalentin Basin Murcia-Spain, and Crete-Greece (Fig. 5b). The next important class was the driest (BGI>150), covering 23.3% of the study field sites, corresponding the study sites of Boteti Area-Botswana, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Mamora Sehoul-Morocco, and Crete-Greece. The next important The wetter climatic conditions with BGI<50, and 50-75 have been defined in 23.2%, and 11.9% of the study field sites, corresponding to the study sites of Nestos Basin Maggana-Greece, Mação-Portugal, Novij Saratov-Russia, Djanybek-Russia, Secano Interior-Chile, Rendina Basin Basilicata-Italy, Nestos Basin Maggana-Greece, Santiago Island-Cape Verde, Gois-Portugal, Cointzio catchment-Mexico, and Santiago Island-Cape Verde. Intermediate conditions of aridity index (BGI 75-100, 100-125) have been found in 6.9% and 8.2% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Eskisehir-Turkey, and Crete-Greece.

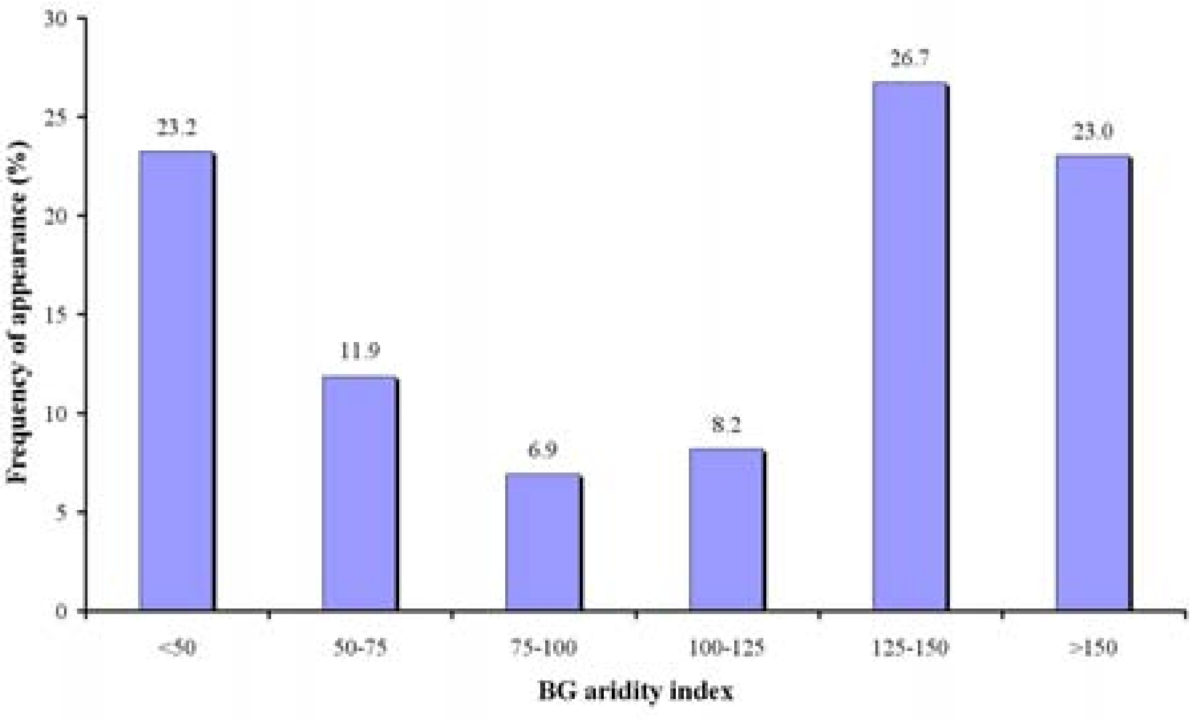

Fig. 5b. Distribution of Bagnouls-Gaussen aridity index classes prevailing in the study field sites

Annual potential evapotranspiration

Potential evapotranspiration (ETo) includes both the potential evaporation from the soil surface and the transpiration by plants. The rate of ETo depends on the existing climatic conditions including radiation energy of the sun, wind speed, air temperature, vapor deficit of the air, and temperature. ETo values are obtained when the water available for this process is non-limiting. In case that soil water availability is limited then the actual evapotranspiration (ETa) occurs receiving values lower than ETo. The ratio of ETa/ETo can be used as an important indicator for assessing aridity of an area. Furthermore, another important climatic index of the average water available in the soil is the ratio between mean annual precipitation (P) and mean annual evapotranspiration (ETo). These are critical environmental factors affecting the evolution of natural vegetation. Rainfall and soil water availability in comparison with ETo values can be used as determinant factors for assessing desertification vulnerability of an area.

The potential evapotranspiration rate was mainly calculated for the various study sites from meteorological data received from the National Meteorological Services. The Penman-Monteith method as modified by Allen (1986) has been applied using the following meteorological data: air temperature, relative humidity, wind speed, and solar radiation. The following classes of potential evapotranspiration have been considered in this study: (a) ETo<500 mm, (b) ETo ranging from 500-800 mm, (c) ETo ranging from 800-1200 mm, (d) ETo ranging from 1200-1500 mm, and (e) ETo>1500 mm.

Data for this indicator were calculated for 1339 field sites, corresponding to 15 study sites (Table 1). Based on the obtained data (Fig. 6), the majority of the study field sites (45.2% of the study field sites have dry climatic conditions with annul potential evapotranspiration rates ranging between 1200-1500 mm per year, in the study sites areas of Novij Saratov-Russia, Djanybek-Russia, Secano Interior-Chile, Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Crete-Greece. The next most important class of potential evapotranspiration rate (ETo 800-1200 mm/yr) was defined in 28.2% 0f the study field sites, corresponding to the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Santiago Island-Cape Verde, Mação-Portugal, Cointzio catchment-Mexico, Gois-Portugal, and Crete-Greece. The wettest climatic conditions were found in 21.0% of the study field sites, corresponding to the study sites of Nestos Basin Maggana-Greece, Eskisehir-Turkey, Mamora Sehoul-Morocco**,** and Konya Karapinar plain-Turkey. Finally the driest climatic conditions with annual potential evapotranspiration rate greater than 1500 mm was found in 5.5% of the study field sites, corresponding to the study sites of Boteti Area-Botswana, and Zeuss Koutine-Tunisia.

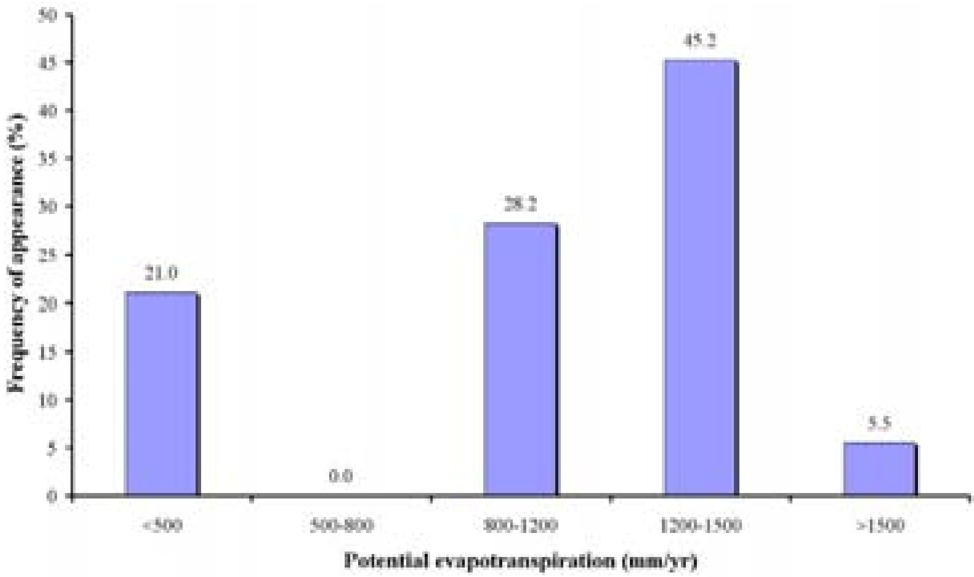

Fig. 6. Distribution of potential evapotranspiration rate prevailing in the study field sites

Rainfall seasonality

Rainfall seasonality is related to the distribution of rainfall during a normal year. An irregular distribution of rainfall means that most of the rainfall occurs in the period from October to May as in the Mediterranean areas. Rainfall seasonality affects soil erosion and vegetation composition and growth. Very high inter-annual rainfall variability causes periods of particularly long drought and sudden and high-intensity rainfall. Under hot and dry climatic conditions the tolerance to erosion of shallow soils in dry badlands with poor vegetation cover is rather low, and rain fed vegetation can no longer be supported, leading to desertification (Fig. 7). Reduced biomass production, in turn, directly affects the organic matter content of the soil and the aggregation and stability of the surface horizon against erosion. In addition reduced vegetation growth is followed by a net decrease of greenhouse gases assimilation by the plants and thus it may contribute to potential climate change at the local and regional scale and to desertification in a broad sense. However, at the same time the existing vegetation under arid and semi-arid climatic conditions exhibits a great capacity of adaptation and resistance to dry conditions, and many species can survive many months through prolonged droughts with soil moisture content below the theoretical wilting point protecting extensive areas from desertification.

Fig. 7. Typical examples of areas with rather seasonal precipitation and short drier season (Eskisehir Plain-Turkey, left) and extreme rainfall seasonality with most precipitation occurring in a period less than 3 months (Santiago Island-Cape Verde, right)

The rainfall seasonality for this project was estimated by the Seasonality Index (SI) (derived by Walsh and Lawler (1981). The following equation has been used for calculating the SI:

$$SIi = \frac{1}{Ri} \sum_{n=1}^{n=12} \left| Xin - \frac{Ri}{12} \right|$$

Where Ri is the total annual precipitation for the particular year under study and Xin is the actual monthly precipitation for month n**.** The season rainfall/total rainfall (%) index takes values from 0 to 100%. The statistical theoretic "normal" value for each season is 25%. The monthly rainfall/total rainfall (%) index has an equal distribution approximately 8% per each month. The bigger the difference from this value, the higher the rain seasonality. The precipitation regime then has been categorized using the classes of SIi delineated in the following Table.

SIi	**Precipitation regime**
<0.19	Precipitation spread throughout the year

0.20-0.39	Precipitation spread throughout the year, but with a definite wetter season
0.40-0.59	Rather seasonal with a short drier season
0.60-0.79	Seasonal
0.80-0.99	Marked seasonal with a long dry season
1.00-1.19	Most precipitation in <3 months

Data for this indicator were calculated for 1399 field sites, corresponding to 17 study sites (Table 1). Based on the existing data, the prevailing climatic conditions are characterized as marked seasonal with long dry season (Fig. 8), covering 37.9% of the study field sites, corresponding to the study sites of Crete-Greece, Djanybek-Russia, Novij Saratov-Russia, Santiago Island-Cape Verde, Konya Karapinar Plain-Turkey, Djanybek-Russia, Mação- Portugal, Mamora Sehoul-Morocco, and Secano Interior-Chile. The following important class of rainfall seasonality has a strong seasonal character with a short drier season measured, covering 29.1% of the study field sites, and particular in the study sites of Crete-Greece, Zeuss Koutine-Tunisia, Gois-Portugal, and Eskisehir Plain-Turkey. Climatic conditions with precipitation spread throughout the year but with a definite wetter season has been found in 16.4% of the study field sites and particularly in the areas of Guadalentin Basin-Spain, Djanybek-Russia, and Novij Saratov-Russia. Areas characterized as seasonal with respect to rainfall distribution have been defined in 15.8% of the study field sites of Boteti Area-Botswana, Nestos Basin Maggana-Greece, Cointzio catchment-Mexico, and the upper mountainous areas of Crete. Some of the study field sites in Santiago Island-Cape Verde have been characterized as the driest with most of the precipitation occurring in a period less than 3 months.

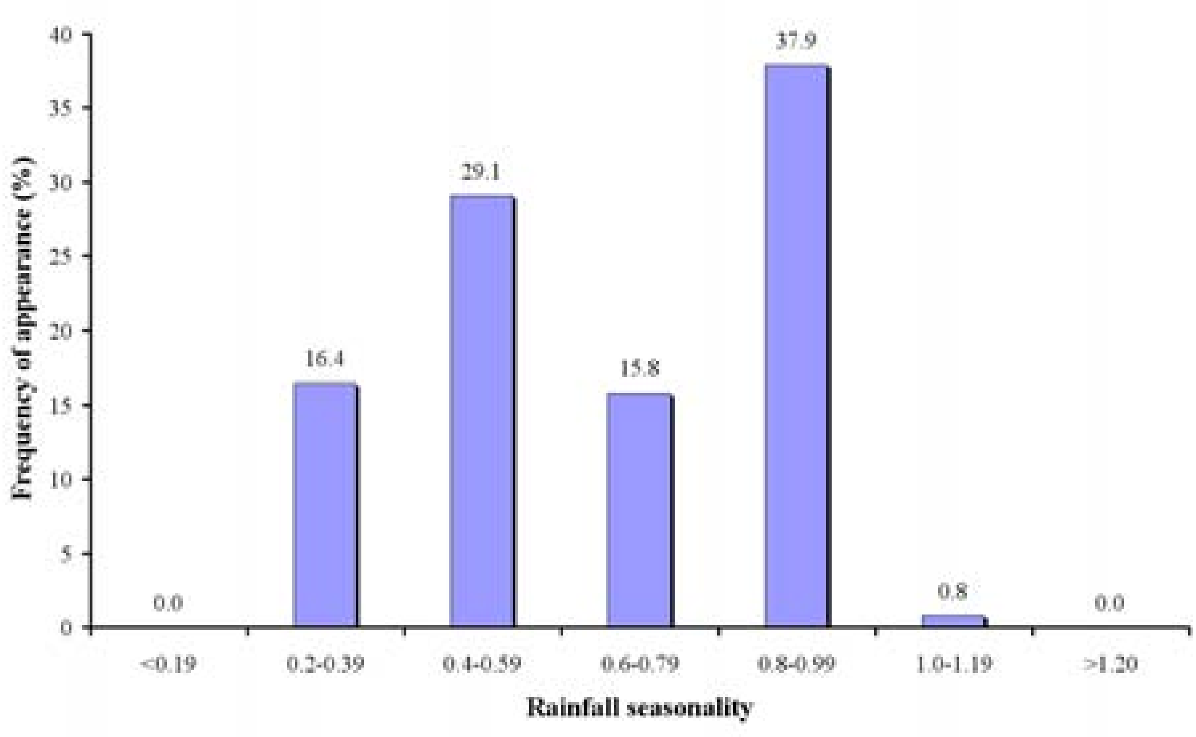

Fig. 8. Distribution of rainfall seasonality classes prevailing in the study field sites

<u>Rainfall erosivity</u>

Rainfall erosivity is a climatic factor which can be determined from local rainfall data. Rainfall erosivity is highly related to soil loss. Increased rain erosivity indicates greater erosive capacity of the overland water flow. Soil erosion by running water occurs where the intensity and duration of rainstorms exceeds the capacity of the soil to infiltrate the rain. Where rainfalls are intense, it is particularly urgent to adopt conservation and management techniques to protect the soil during the rainy season. Rainfall erosivity depends primarily on rainfall intensity and amount. For calculating erosivity the modified version of the Fournier index (FI) has been used as follows:

$$FI = \sum_{i=1}^{12} Pi^2 / p$$

Where Pi is the precipitation total in month i, and p is the mean annual precipitation total. The Fournier index has been classified as in the following Table:

Class description	Fournier index (FI) range
Very low	< 60
Low	60–90
Moderate	91-120
High	121-160
Very high	>160

Data on rain erosivity have been collected in 948 study field sites, corresponding to 12 study sites. The dominant classes of the rain erosivity indicator were two, with values from very low to low, covering 47.0%, and 28.3%, respectively, of the study field sites (Fig. 9). Such rain erosivity classes have been described in field sites of the following study sites: Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Secano Interior-Chile, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, Konya Karapinar plain-Turkey, Mamora Sehoul-Morocco, and Crete-Greece. High or very high rainfall erosivity values have been estimated in 8.5%, and 15.3% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Crete-Greece, Cointzio catchment-Mexico, and Djanybek-Russia. However, in the study site of Santiago Island-Cape Verde have been identified in a few cases very high rain erosivity values.

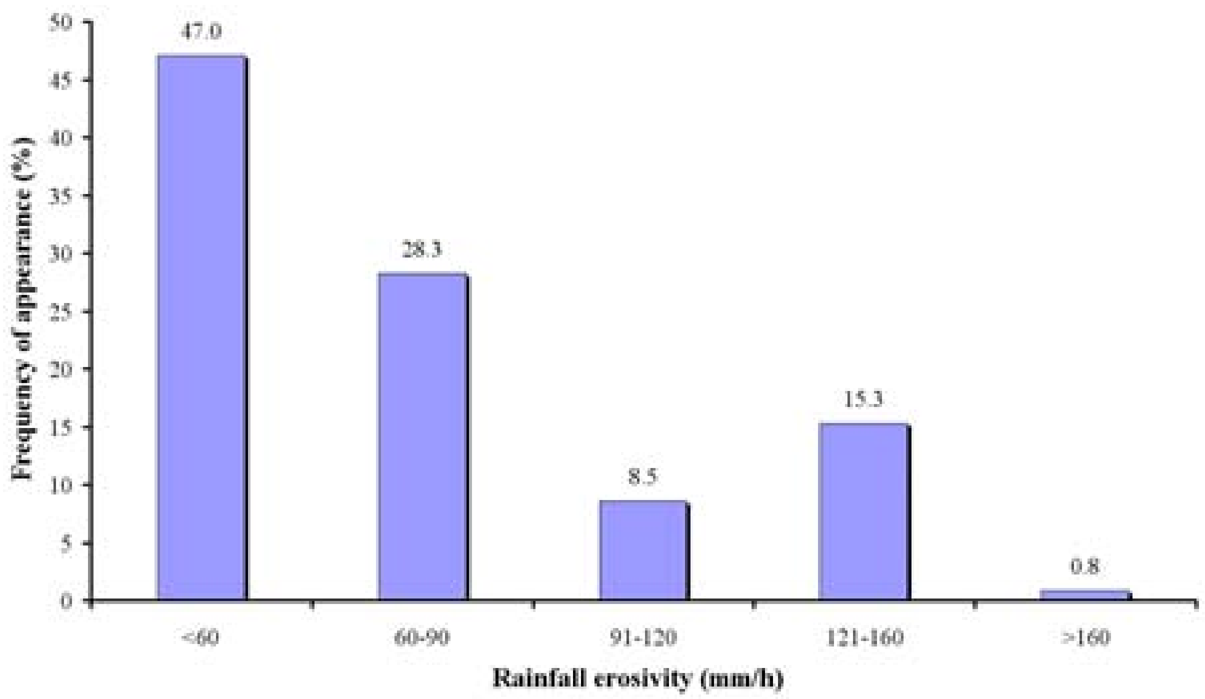

Fig. 9. Distribution of rain erosivity classes prevailing in the study field sites

2.2 Indicators related to water

In the last four decades, favorable soil and climatic conditions, new technologies of farming, the increasing demands for foods and the availability of ground or surface water has resulted in intensive farming of the lowlands as well as hilly lands. Furthermore, the development of fast transportation means and the availability of cheap holiday-offers have encouraged the expansion of domestic and international mass tourism over the last 30 years. The increasing tourism exerts a series of impacts on the environment and particular on the land-use patterns and the allocation of water resources. Most of the population in Europe is concentrated near or in the coastal zones, and increasing tourism in the southern part causes a strong, seasonal water demand. Thus, uneven water demands in both space and time greatly increase the cost of making water accessible.

Currently water resources are under severe physical, social, economic and environmental stresses, compounding to the water uses problems. The need for intensification of agriculture to meet the high cost of production, the use of poor quality of water (sea water intrusion), the lack of drainage systems are in many cases responsible for soil degradation resulting from water logging, salinization, alkalinization, and soil erosion. Land degradation and water scarcity mutually re-enforce each other and drylands where water scarcity is increasing, the process of desertification becomes faster and extensive. Salinization is one of the key processes that could lead to desertification especially the plain areas along the coast. It is a growing problem all over the world and affects million of hectares in Europe. Agriculture plays a major role in by causing a high water consumption and water chemical degradation, but at the same time is the economic sector that is facing the most severe impacts. The selected indicators to be used related to water for assessing desertification risk in this project is: (a) water quality, (b) water quantity, (c) ground water exploitation, and water consumption/water demands. Water demands for irrigation should also include leaching requirements. Data related to water have been collected in 5 study sites (Table 2). The number of questionnaires filled in each study site and for each indicator appears in Table 2.

Table 2. Number of field sites in which the indicators related to water was recorded in the filled questionnaires

site no	Study site	Number of field sites described for the indicator			
		Water Quality	Water Quantity	Groundwater exploitation	Water consumption/Water demands
1	Mamora/Sehoul, Morocco	-	-	-	-
2	Rendina Basin, Basilicata, Italy	-	-	-	-
3	Secano Interior, Chile	-	-	-	-
4	Loess Plateau, China	-	-	-	-
5	Mação, Portugal	-	-	-	-
6	Konya, Karapinar plain, Turkey	-	-	-	-
7	Eskisehir, Turkey	-	-	-	-
8	Santiago Island, Cape Verde	-	-	-	-
9	Zeuss-Koutine, Tunisia	-	-	-	-
10	Guadalentin Basin, Murcia, Spain	-	-	-	-
11	Boteti Area, Botswana	19	19	19	19

12	**Nestos Basin, Maggana, Greece**	**30**	**30**	**30**	**30**
13	**Djanybek, Russia**	**98**	**98**	**98**	**98**
14	**Novij, Saratov, Russia**	**100**	**100**	**100**	**100**
15	**Crete, Greece**	**114**	**114**	**114**	**114**
16	**Gois, Portugal**	**-**	**-**	**-**	**-**
17	**Cointzio watershed-Mexico**	**-**	**-**	**-**	**-**
	TOTAL	**361**	**361**	**361**	**361**

<u>Water quality</u>

The criteria for good water quality for irrigation in agriculture are: low salinity and low ratio of Na^+ to Ca^{2+} Mg^{2+}. The index usually used to characterize the quality of irrigation water with respect to its influence on the exchangeable sodium percentage (soil sodification) is the sodium adsorption ratio (SAR) which is defined as follows:

$$\mathbf{SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}])/2** (1/2).}$$

This is the ratio of the sodium ion (Na^+) concentration to the square root of the average concentration of the divalent calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. One main reason of increasing amounts of salts in aquifers is sea-water intrusion due to over-exploitation resulting from increasing water demands for multiple uses. The use of poor quality water for irrigation and under certain soil and climatic conditions leads to soil salinization (Fig. 10). Increasing salt levels in the top soil layers can affect plant growth and productivity. High concentrations of various salts (e.g., sodium chloride, magnesium and calcium sulphates and bicarbonates) affect plants growth both directly by their toxicity and indirectly by increasing osmotic potential and lowering root water uptake. In dry climates continuous salt accumulation could lead to desertification, while in humid or subhumid climates moderate or severe salinization may occur periodically. Electrical conductivity of water has been used as a handy measurement for the purpose of this project. The following classes of electrical conductivity (EC) in µS have been defined: (a) EC<400 µS, (b) 400-800 µS, (c) 800-1500 µS, and (d) >1500 µS.

Fig. 10. Salt affected areas due to poor quality of ground water causing soil salinization resulting from high rates of evaporation (Botswana, left) and irrigation with high concentration of salts (Spain, right)

As Table 2 shows, water quality data used for irrigation have been collected in 361 field sites, corresponding to 5 study sites. High quality of irrigation water (electrical conductivity <400 μS) has been found in 46.8% of the study field sites located mainly in Novij Saratov-Russia and partially in Crete-Greece (Fig. 11). Low to very low quality of irrigation water (800-1500, >1500 μS) has been recorded in 25.8% and 18.3% of the study field sites, respectively. Such low water quality has been measured in some field sites of Crete-Greece, Djanybek-Russia, Boteti Area-Botswana, and in Nestos Basin Maggana-Greece. Moderate quality of irrigation water (electrical conductivity 400-800 μS) has been found in 9.1% of the study field sites located in some areas of Crete-Greece and in Boteti Area-Botswana.

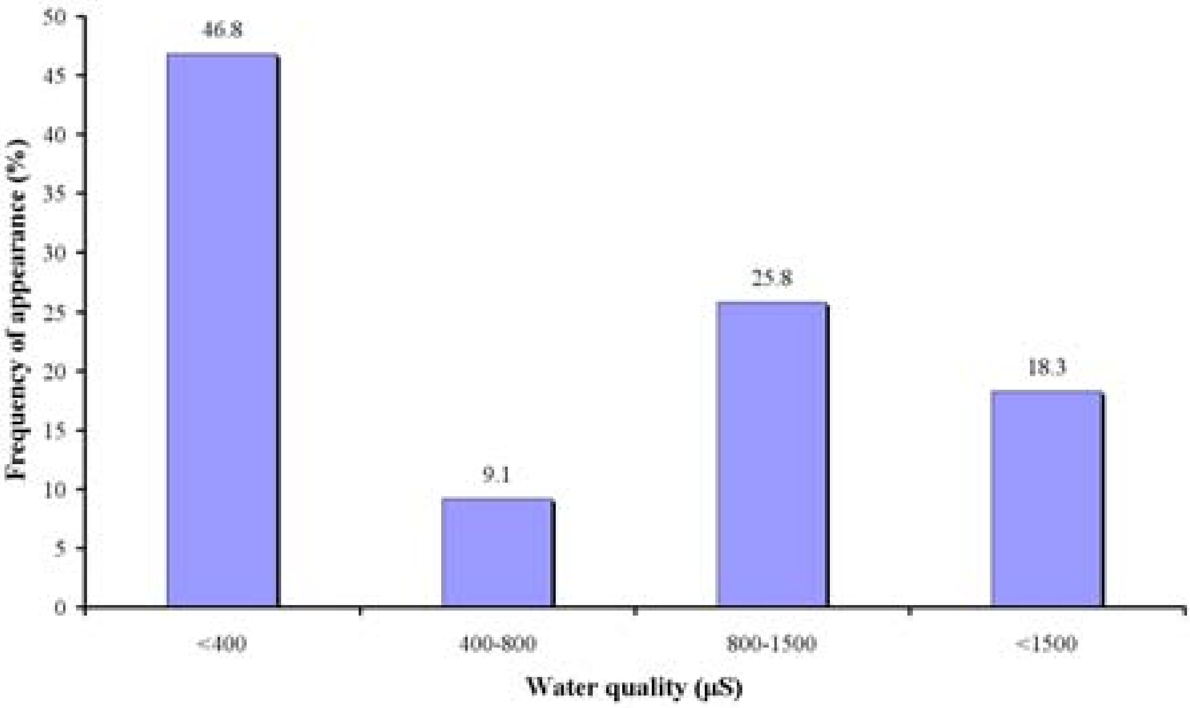

Fig. 11. Distribution of irrigation water quality classes prevailing in the study field sites

<u>Water quantity</u>

Knowledge of water resources of a region are of great importance for the local economy. Water resources in European Union, particularly for the Southern regions, seem under severe physical, social, economic and environmental stresses, compounding to the water uses problems. Water scarcity is a natural phenomenon since water on the earth has been distributed in a non-uniform way with its allocation changing over time. Groundwater resources include deep and shallow aquifers that are connected to rivers, streams or seas. For a quantitative analysis it is important to have sound estimates of the recharge of the aquifer over a given time period as well as its interactions with surface waters (recharge and discharge). For an assessment of groundwater resources it is essential to have repeated observations of groundwater levels at a relatively large number of observation wells, since groundwater systems respond to short-term and long-term changes in climate, groundwater withdrawal and (artificial) recharge and land uses. Surface waters encompass both rivers and lakes and can quantitatively be assessed by long term averages of the available water resulting from endogenous precipitation.

As Table 2 shows, water quality characteristics used for irrigation have been collected in 361 field sites, corresponding to 5 study sites areas. Based on the obtained data, water quantity available for use is characterized as moderate in 37.7% of the study field sites (Fig. 12) and specifically in some areas of the sites Crete-Greece, Djanybek-Russia, and Boteti Area-Botswana. The quantity of water has been characterized as adequate in 32,7% of the study field sites and particularly in Nestos Basin Maggana-

Greece, and in some cases for the study sites of Crete-Greece, Novij Saratov-Russia, and Boteti Area-Botswana. The water quantity is characterized as low in 29.6% of the study field sites corresponding to all above mentioned 4 study sites (Fig 12).

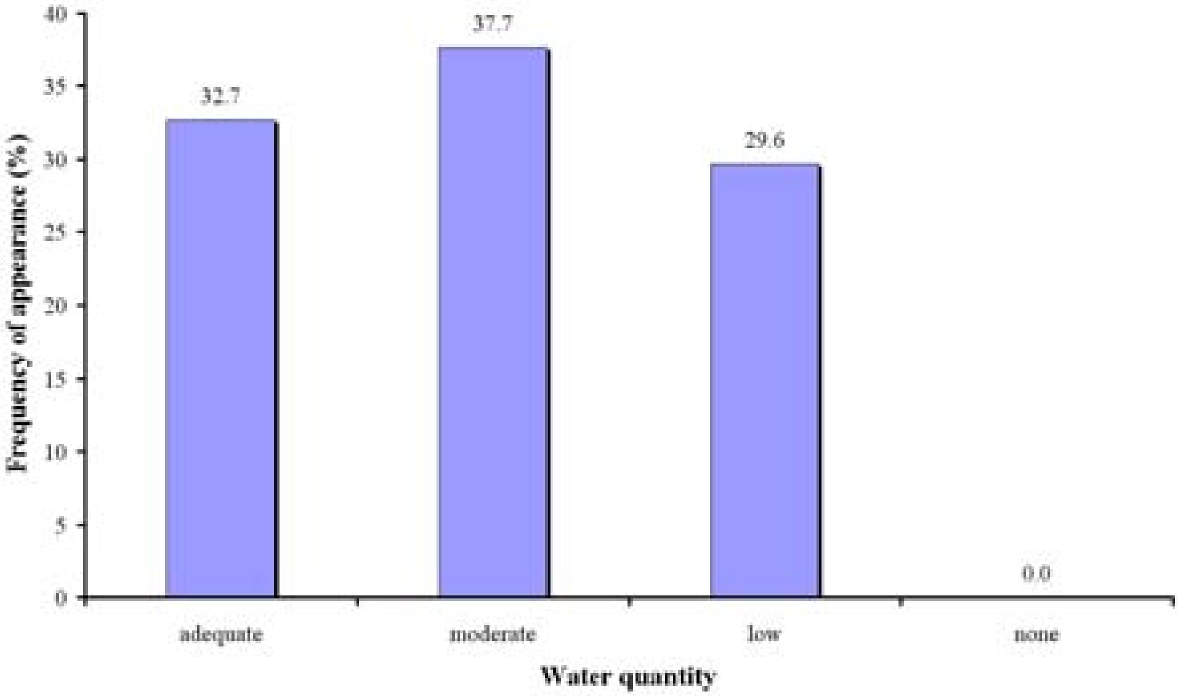

Fig. 12. Distribution of water quantity classes prevailing in the study field sites

Ground water exploitation

Agriculture plays a major role in water extraction and consumption especially in Mediterranean coastal areas where intensive irrigated horticulture is widespread. Nevertheless, in many areas a large contribution to aquifers overexploitation is due to the industrial and residential sectors and, seasonally, to tourism. Ground water exploitation can be estimated by "the exploitation index" that is defined as withdrawal of conventional freshwater resources (surface and groundwater) over total renewable resources (expressed in %). Ground water over-exploitation describes the degree to which the amount of water pumped from aquifers is sustainable in relation to the water that is available. This indicator considers the potential supply in relation to what is actually used. Over-exploitation can be quantitatively analyzed by comparing groundwater natural recharge quantities with the quantities of water actually used, but it can also be seen from undesirable effects such as the drawdown in well, drying up of rivers and springs. Specifically, this indicator is estimated by assessing: (a) water consumption by various sectors, (b) the decrease in river and spring flow, ground water monitoring, and (c) comparing by an appraisal of the natural recharge rate in a certain hydrological area.

As Table 2 shows, water exploitation characteristics have been collected in 361 field sites, corresponding to 5 study sites. The obtained data from the questionnaires showed that ground water exploitation trends is without problems of over-exploitation in the majority (62.6%) of the study field sites (Fig. 13), particularly in the sites of Djanybek-Russia, Novij Saratov-Russia and in some cases in Boteti Area-Botswana and Crete-Greece. The ground water exploitation is greater than 80% of recharge but recharge never reach to the quantities consumed by the various users in 22.4% of the study field sites (some cases in Crete-Greece). Some local problems of over-exploitation and over-exploitation in the broad scale of the study sites have been found in some field sites in Boteti Area-Botswana and in the whole area Nestos Basin Maggana-Greece (Fig 13).

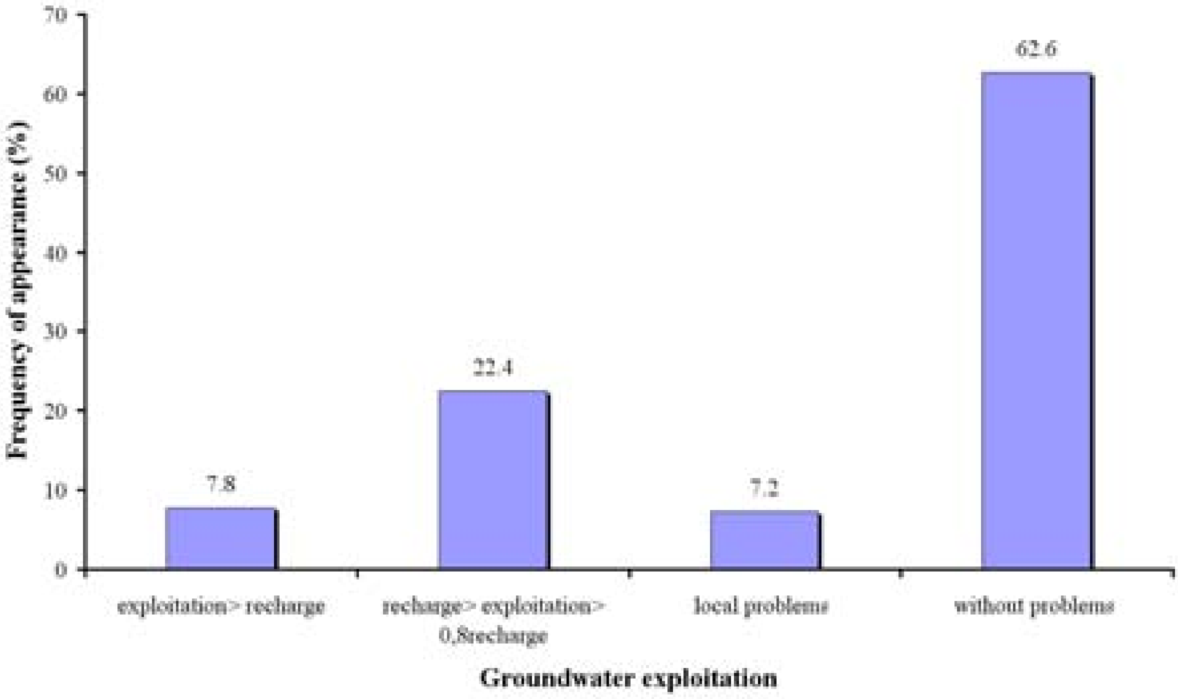

Fig. 13. Ground water exploitation trends prevailing in the study field sites

Water consumption/water demands

Various concepts may be used to describe the diverse aspects of water use. Water abstraction is the quantity of water physically removed from its natural source. Water supply refers to the share of abstraction which is supplied to users excluding losses in storage, conveyance and distribution. Water consumption signifies the share of supply which in terms of a water balance actually is used (as evaporation), while the remainder is reintroduced into the source of abstraction. The term water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way, it is often considered equal to water abstraction, although conceptually the two terms do not allow for the same interpretation. This indicator has been estimated for the purposes of the DESIRE project by computing: (a) the amount of water used and (b) the corresponding demands for domestic, industrial, agricultural and other sectors. The percentage of total consumption by each sector dividing the total consumption or by the corresponding demands for each sector determines the indicator. In this project, the total consumption in all sectors versus the total demands has been used. The following classes have been defined for this indicator: (a) low - water consumption/water demands = WC/WD <0.5), ( ) moderate - WC/WD = 0.5-1, (c) high - WC/WD = 1-2, and (d) very high - WC/WD >2. In the case of irrigation WC/WD< 1 poses threats of biomass loss and soil salinization, WC/WD> 1 results in water waste and soil erosion on sloping land.

As Table 2 shows, water consumption/water demands data have been collected in 361 field sites, corresponding to 5 study sites. The obtained data have shown that 44.0% of the study field sites had a low ratio of WC/WD (Fig. 14). This has been observed mainly in the study sites of Djanybek-Russia, Novij Saratov-Russia and partially in the study sites of Crete-Greece and Boteti Area-Botswana. Moderate and high classes of WC/WD have been found in about equal number of study field sites (23.3% and 24.9% of the total field sites, respectively) covering parts of Crete-Greece, Boteti Area-

Botswana, and Novij Saratov-Russia. Very high ratio of WC/WD has been computed in the study field sites of Nestos Basin Maggana-Greece.

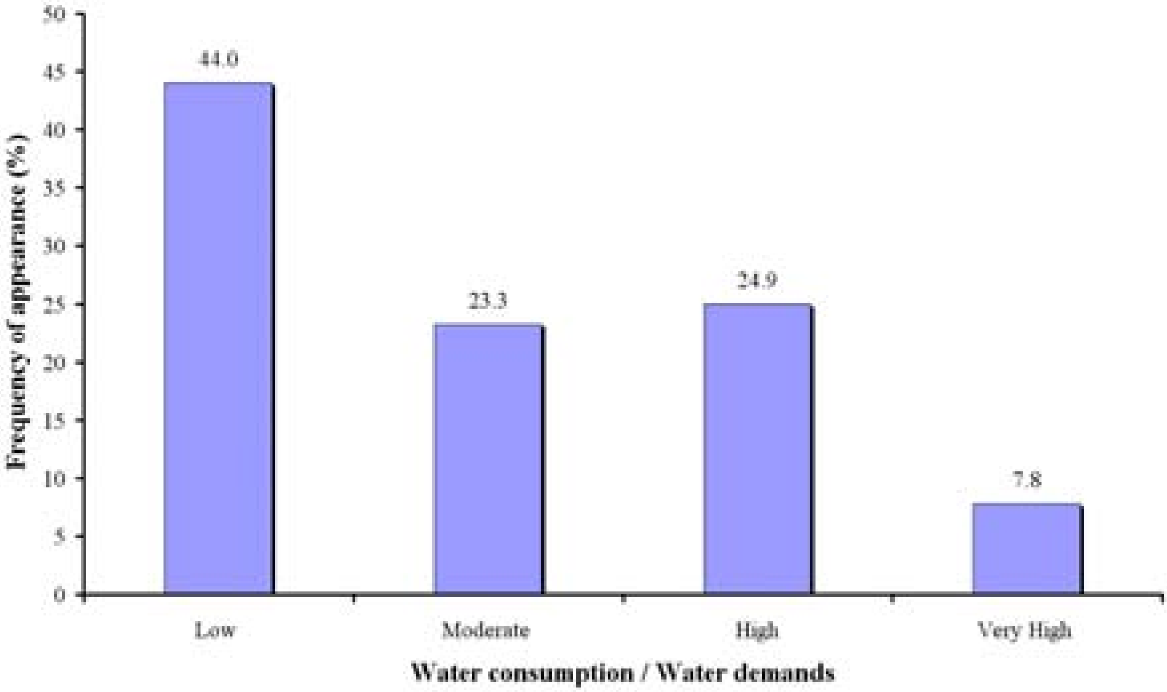

Fig. 14. Water consumption versus water demands classes prevailing in the study field sites

2.3 Indicators related to the soil

Soil is a dominant factor of the terrestrial ecosystems in the semi-arid and dry sub-humid zones, particularly through its effect on plant growth. Vegetation degradation will proceed, in a certain landscape, when the soil is not able to provide the plants with adequate rooting space for water and nutrients adsorption. One of the most important processes of desertification is soil erosion, particularly affecting hilly areas. Desertification due to soil erosion is a serious threat to the soil quality and land productivity. The effects of soil erosion on land productivity depend largely on the thickness and quality of the topsoil and on the nature of the subsoil. Any loss of soil volume from marginal lands greatly reduces the potential for biomass production, ultimately leading to desertification. In the semi-arid and the sub-humid zones, the land becomes irreversibly desertified when the rootable soil depth is not capable of sustaining a certain minimum vegetation cover. There are cases where desertification proceeds even on deep soils, when their water balance is not capable of meeting the needs of plants.

Soil quality indicators used for the purposes of the DESIRE project to define desertification risk are related to water availability, and erosion characteristics. Selection of soil quality indicators considering the multiple functions of soil in maintaining productivity and environmental well-being is a complicated issue and it requires integrating physical, chemical and biological soil attributes that define those functions. The indicators selected for this study are simple soil properties or characteristics given in regular soil survey reports, such as: drainage, soil depth, soil texture, parent material, slope gradient, slope aspect, stoniness, water storage capacity, degree of erosion, rock outcrops exposure, organic matter content in the surface horizon, and soil electrical conductivity.

Soil drainage

Soil drainage is related to how rapidly excess water leaves the soil by runoff or internal drainage. Internal drainage is referred to downward movement of water into the soil profile and it affects the redistribute of soil water to lower depths of the profile, thereby increasing the water content at the subsoil. Drainage is classified in classes according to the term which generally describes the condition of how long the soil is free of saturation, for example in a well drained soil water is removed very rapidly and no occurrence of internal free water is observed. On the contrary, in a poorly drained the soil is saturated for a long period resulting in the formation of mottles of iron and manganese in the upper 30 cm of the soil, or grey colors of reducing conditions, with a permanent water table usually at a depth greater than 75 cm. Poor drainage is not associated with desertification, but with the loss of profit from cultivated plants. Excessive drainage in coarse textured soils, on the other hand, may contribute to desertification.

Soil drainage conditions for the purpose of the this study have been defined on the basis of the depth of hydromorphic features such as iron or manganese mottles or gray colors, and depth of the groundwater table. The following drainage classes have been distinguished:

Very well to well drained soils

Soils with any Fe or Mn mottles or gray colors at some depth greater than 100 cm from the soil surface. The soil is not wet enough near the soil surface or the soil does not remain wet during the growing period of the plants. Water is removed from the soil rapidly (Fig. 15).

Moderately well to somewhat poorly drained soils

Fe, Mn or gray mottles are present in the soil, at some depth between 30 and 100 cm from the soil surface. The soil is wet enough near the soil surface or the soil remains wet during the early growing period of the plants. Water is removed from the soil slowly.

Poorly drained soils

Mottles of Fe and Mn are present in the upper 30 cm of the soil, or gray colors of reducing conditions are present. A permanent water table usually exists at a depth greater than 75 cm. In some of these soils the ground water may reach to the surface during the wet period of the year. Water is removed from the soil so slowly that the soils are wet at shallow depth for long periods.

Very poorly drained soils

Mottles of Fe and Mn are present in the upper 30 cm of the soil, or gray colors of reducing conditions are present. A permanent water table usually exists at a depth less than 75 cm. In many of these soils the ground water may reach to the surface during the wet period of the year. Water is removed from the soil so slowly that the soils are wet at shallow depth for long periods.

Fig. 15. Example of well drained soil (left) and very poorly drained soil (right)

Soil drainage has been described in 446 field sites, corresponding to 6 study sites (Table 3). Soil drained conditions are related to physiographic and topographic conditions. Soils on slopping areas are usually well drained. On the contrary, soils found in plain areas located at the lower concave physiographic positions close to water bodies or having a ground water table close to the soil surface are usually poorly drained. The obtained data in part of the study sites (Table 3) showed that well drained soils are dominant covering 40.7% of the total study field sites (Fig. 16). Such soils have been mainly found in the study sites of Konya, Karapinar plain-Turkey, Novij Saratov-Russia, and some in Crete-Greece, and Boteti Area-Botswana. The next important class identified is very poorly drained soils covering 33.0% of the study field sites, located mainly in Djanybek-Russia, and in some cases in Crete-Greece, and Boteti Area-Botswana. Poorly drained soils cover 16.1% of the study field sites located mainly in Novij Saratov-Russia, and in Crete-Greece. Areas with poorly and very poorly drained soils are sensitive to desertification under semi-arid or dry-subhumid climatic conditions due to soil salinization. Finally imperfectly drained soils were mainly found in some sites of Boteti Area-Botswana, Crete, Greece, Nestos Basin Maggana-Greece, and Novij Saratov-Russia.

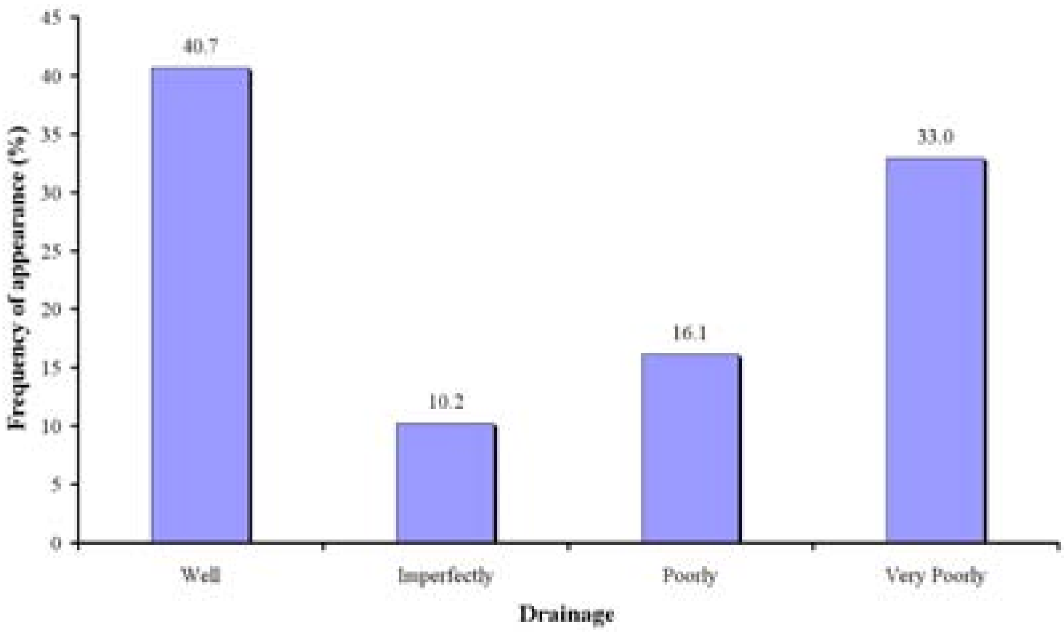

Fig. 16 Distribution of soil drainage conditions prevailing in the study field sites

Table 3**. Number of field sites in which the indicators related to soils was recorded in the filled questionnaires**

site no	Study site	Number of field sites described for the indicator											
		Drainage	Parent material	Rock fragments.	Slope aspect	Slope gradient	Soil depth	Soil texture	Water storage capacity	Rock outcrop	Organic matter	Degree of soil erosion	Electrical conductivi
1	Mação, Portugal	-	-	-	31	-	31	-	-	-	-	31	-
2	Nestos Basin, Maggana, Greece	30	30	-	-	-	30	30	30	-	-	-	30
3	Rendina Basin, Basilicata, Italy	-	30	30	-	30	30	30	-	-	30	30	-
4	Secano Interior, Chile	-	28	28	28	28	28	28	28	28	28	28	-
5	Boteti Area, Botswana	24	50	48	49	48	54	55	47	45	36	40	7
6	Eskisehir, Turkey	-	70	70	70	70	70	70	70	70	70	70	-

7	**Konya, Karapinar plain, Turkey**	**74**	**74**	**74**	**74**	**74**	**74**	**74**	**74**	**74**	**74**	**74**	**-**
8	**Loess Plateau, China**	**-**	**150**	**150**	**-**	**150**	**150**	**150**	**-**	**-**	**150**	**150**	**-**
9	**Novij, Saratov, Russia**	**100**	**122**	**84**	**84**	**84**	**122**	**122**	**122**	**84**	**22**	**22**	**38**
10	**Djanybek, Russia**	**98**	**138**	**69**	**69**	**69**	**138**	**138**	**138**	**69**	**40**	**40**	**69**
11	**Santiago Island, Cape Verde**	**-**	**103**	**103**	**103**	**103**	**103**	**103**	**103**	**103**	**103**	**103**	**-**
12	**Mamora/Sehoul, Morocco**	**-**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**-**
13	**Zeuss-Koutine, Tunisia**	**-**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**-**
14	**Guadalentin Basin, Murcia, Spain**	**-**	**121**	**121**	**121**	**121**	**121**	**121**	**121**	**121**	**121**	**121**	**-**
15	**Crete, Greece**	**114**	**269**	**155**	**155**	**155**	**269**	**269**	**269**	**155**	**155**	**155**	**114**
16	**Cointzio watershed, Mexico**	**-**	**67**	**67**	**87**	**67**	**87**	**67**	**67**	**67**	**67**	**87**	**-**
17	**Gois, Portugal**	**-**	**-**	**-**	**30**	**-**	**30**	**-**	**-**	**-**	**-**	**30**	**-**
	TOTAL	**440**	**1492**	**1239**	**1141**	**1239**	**1577**	**1497**	**1309**	**1056**	**1136**	**1221**	**258**

Parent material

Parent material is considered as a soil-forming factor affecting soil properties, plant growth, soil erosion and ecosystem resilience. Residual soils have specific physical and chemical characteristics closely related to the parent material. For example soils formed on limestone are usually moderately fine- to fine-textured, slow permeable, with neutral to high pH, high base saturation and high nutrient status. However, carbonate enriched soils may induce minor element deficiencies to sensitive plants. On the contrary, soils formed on acid igneous are usually medium-textured, highly permeable, low pH, low base saturation, and low nutrient status.

Areas with soils formed on different types of parent materials exhibit various degrees of sensitivity to land degradation and desertification. For example, limestone produces shallow soils with a relatively dry moisture regime characterized by moderate erodibility and slow vegetation recovery (Fig. 17). Many areas with soils formed on limestone have been greatly degraded and decertified. Areas with soils formed on shale are normally characterized by high productivity, may supply appreciable amounts of previously stored water to the stressed plants protecting areas from desertification. On the other hand, soils formed on marl, despite their considerable depth and high productivity in normal and wet years, they are very susceptible to desertification, unable to support any annual vegetation in particularly dry years due to adverse soil physical properties. They also frequently form surface crust inhibiting water infiltration and increasing surface runoff.

Fig. 17. Areas under the same climatic conditions with soils formed on shale (left) and limestone (right) subjected to different degree of desertification

Parent material has been classified in this study based on existing systems of classification. The various types of parent materials prevailing in the study sites were grouped into the following classes according to their petrology and mineralogical composition:

Major class	Group	Type
Igneous rock	acid igneous	Granite, grano-diorite, quartz-diorite, rhyolite
		Pyroclastics
	basic igneous	Gabbro, basalt, dolerite
	ultrabasic igneous	Peridotite, pyroxenite, ironstone, serpentine
Metamorphic rock	acid metamorphic	Quartzite, gneiss
		Slate, phyllite
	basic metamorphic	Schist, gneiss rich in ferro-magnesian,
		Marble
Sedimentary rock	clastic sediments	Conglomerate,
		Sandstone,
		Siltstone, mudstone, claystone, shale
		Limestone
		Marl
Unconsolidated		Fluvial
		Lacustrine
		Marine
		Colluvial

As Table 3 shows 1492 study field sites were described, corresponding to 15 study sites. The prevailing parent materials are sedimentary rocks such as limestones, marl, and conglomerates in 47.5% of the study sites (Fig 18). Sedimentary materials were found in all study sites except for Secano Interior-Chile, Nestos Basin Maggana-Greece, and Loess Plateau-China study sites. The next important parent material is unconsolidated deposits consisting mainly of alluvial deposits covering 31.8% of the study field sites. Such types of parent material have been found in all study field sites of Nestos Basin Maggana-Greece, and Loess Plateau-China, and in some cases in the other study sites except for Djanybek-Russia, Boteti Area-Botswana, and Konya Karapinar Plain-Turkey. Acid igneous, basic igneous and metamorphic parent materials were found in few cases with frequency of appearance 8.9%, 5.2% and 5.8%, respectively. Such soil parent material have been mainly found in the study sites of Djanybek-Russia, Novij Saratov-Russia, Santiago Island-Cape Verde, Eskisehir Plain-Turkey, Secano Interior-Chile, Cointzio catchment-Mexico, and Rendina Basin Basilicata-Italy.

<u>Rock fragments</u>

Pieces of rocks of 2 mm diameter or larger that are strongly cemented or more resistant to rupture are called rock fragments. They are present on the soil surface or distributed in various quantities into the soil body. Rock fragments, especially on the soil surface can have a great but variable effect on soil water conservation and soil erosion. Cobbles generally restrict evaporative water loss during periods of no- to moderate drought (e.g. from late fall to early summer) but they increase evaporation during the dry and hot summer. The higher amounts of soil moisture in stony soils, especially in late spring to early summer, positively affect plant growth and productivity of rainfed crops supporting a considerable biomass production, and protecting large areas from desertification. Pebbles on the soil surface can reduce surface water runoff and soil loss playing an important role on land protection from desertification. Soils containing considerable amount of rock fragments become warmer earlier in spring than the same soils free of rock fragments. This favors early plant growth and better use of available water.

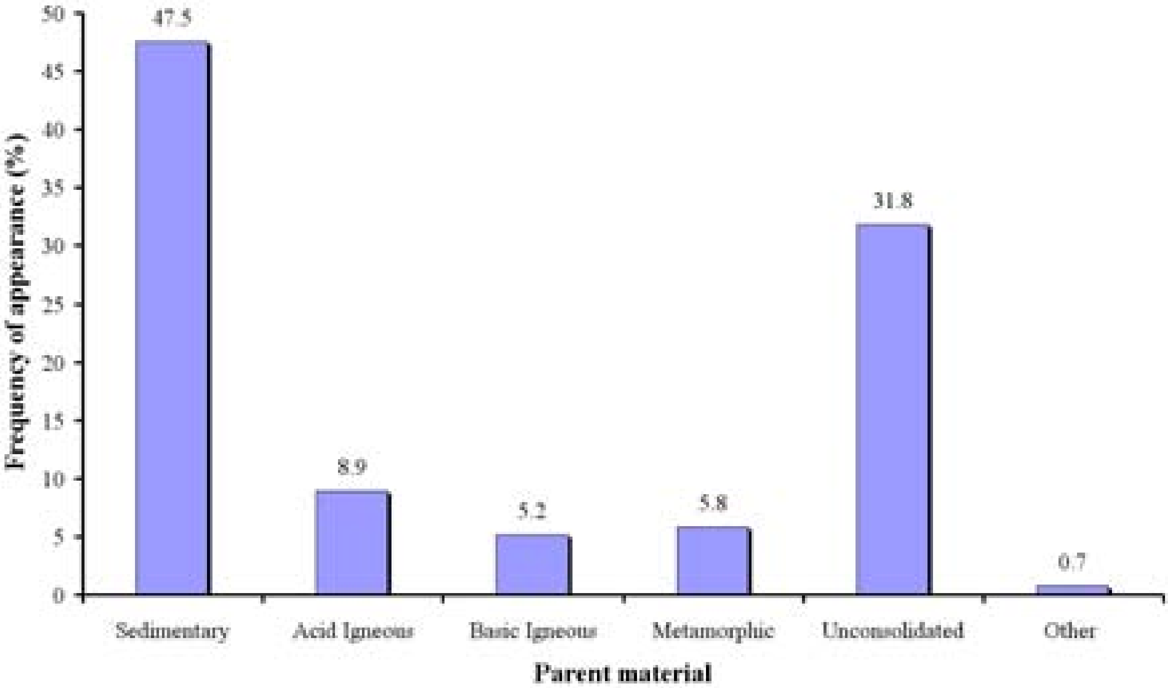

Fig. 18 Distribution of soil parent material prevailing in the study field sites

Rock fragments are classified according to their diameter to the following categories: pebbles (diameter 2-75 mm), cobbles (diameter 75-250 mm), stones (diameter 250-600 mm), and boulders (diameter >600 mm). The percentage cover of the soil surface by rock fragments (RF) has been measured for the purpose of this project using the following four classes: (a) RF>80, (b) RF=40-80%, (c) RF=15-40%, and (d) RF<15%.

Rock fragments data have been collected from 1239 field sites, corresponding to 14 study sites (Table 3). The obtained data have shown that the majority (58.6%) of the field sites were free or with small amount of rock fragments (<15%) on the soil surface (Fig 19). All field sites described in Plateau-China and in Djanybek-Russia were free of rock fragments while in some cases have been measured in the rest of the study field sites. The next important class of rock fragment content was 15-40% found in 25.1% of the study field sites. Such field sites were found in all the rest study sites except for Plateau-China, Cointzio catchment-Mexico, and Djanybek-Russia. This class of rock fragment content on the soil surface is considered as the optimal for soil erosion protection. High amounts (40-80%) and very high amounts (>80%) have been measured in few field sites 10.7% and 5.6%, respectively. Such soils are characterized as very gravelly or skeletal resulting mainly from high erosion rates. They were found mainly in all study sites except for Plateau-China, Konya Karapinar plain-Turkey and Djanybek-Russia.

<u>Slope aspect</u>

Slope aspect is defined as the orientation of the lands with respect to the sun. Slope aspect is considered an important factor for land degradation processes affecting the microclimatic conditions by regulating the angle and the duration at which the sun's rays strike the surface of the soil. Variation in slope aspect and elevation influence the distribution of energy, atmospheric water, plant nutrients and vegetation by varying the exposure of the soil to wind and precipitation and the conditions for natural drainage and soil erosion. In Mediterranean climatic conditions slopes with southern and western facing aspects are warmer and have higher evaporation rates than northern and eastern aspects. Therefore, a slower recovery of vegetation is expected on southern and western aspects, and higher erosion rates than on northern and eastern aspects. As a consequence, southern exposed slopes usually are more degraded or are more sensitive to desertification than northern exposed slopes.

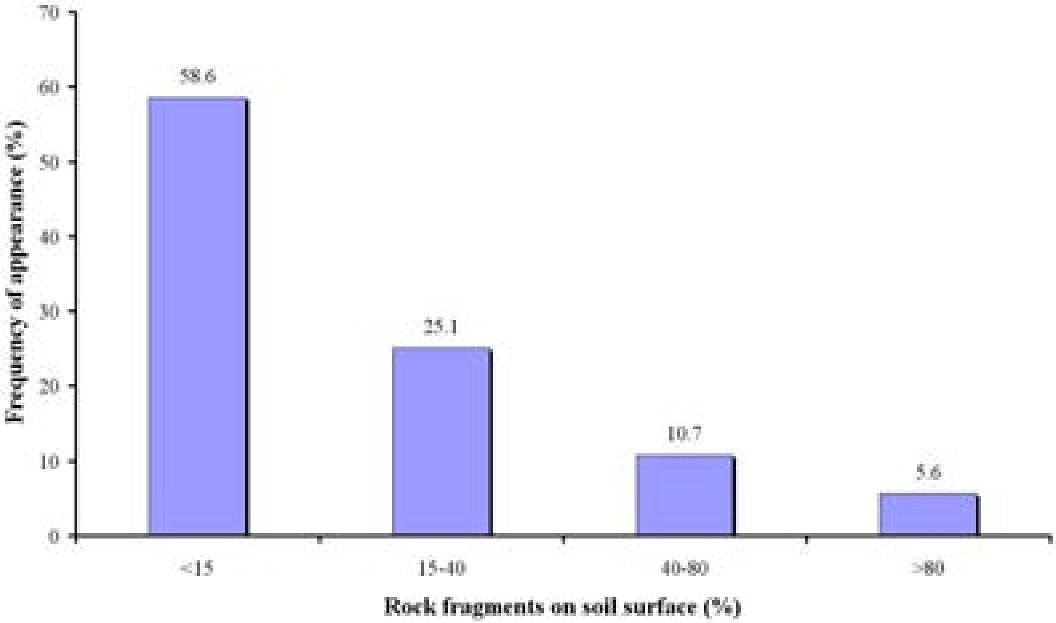

Fig. 19 Rock fragment content on the soil surface prevailing in the study field sites

Slope aspect in this study has been defined by using a compass or by assessing the relative land's surface with respect to the magnetic north. The following classes have been defined: (a) N, NW, NE, (b) S, SW, SE, and (c) plain areas.

As Table 3 shows this indicator has been described in 1141 field sites, corresponding to 14 study sites. The majority of the cases measured (61.2%) are northern facing slopes or plain areas, while the rest (38.7%) are southern facing slopes (Fig. 20). Both slope aspect classes have been identified in all study sites.

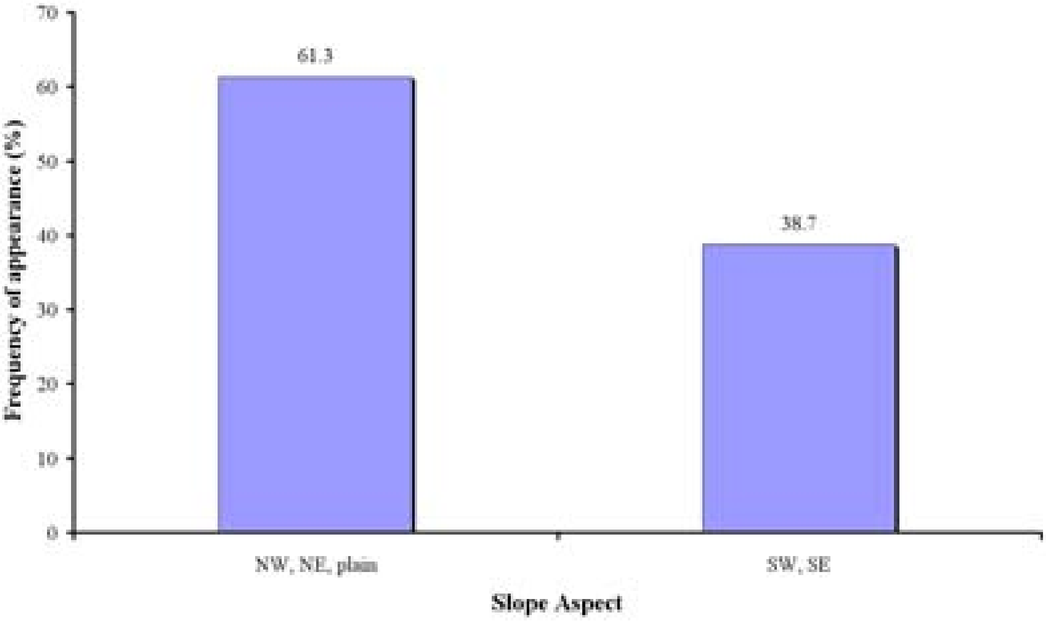

Fig. 20. Distribution of slope aspect classes defined in the study field sites

Slope gradient

Slope gradient greatly affects the amount of surface run-off and soil sediment loss. Soil erosion rates become acute when slope angle exceeds a critical value and then increases logarithmically. Studies conducted in the island of Lesvos (Greece) have shown that soil erosion was moderate or high in slope gradients greater than 12%. Slope gradient can have variable effect in different climatic zones, depending mainly on annual rainfall. Generally, soil sediment loss can be estimated by the product of the amount of surface run-off times the slope gradient times a constant related to soil surface characteristics. As the slope becomes steeper, the runoff coefficient increases, the kinetic energy and carrying capacity of surface water flow becomes greater, soil stability and slope stability decreases, and soil sediment loss increase. Therefore, slope gradient is undoubtedly considered as one of the most important determinants of soil erosion and desertification in hilly areas, when they loose their protective vegetation.

Data for this indicator were collected in 1239 field sites, corresponding to 14 study sites (Table 3). As Fig. 21 shows, 26.3% of the total study fields were almost flat with slope gradient less than 2%. Such areas have been described in all study sites except Santiago Island-Cape Verde. Extensive plain areas have been identified mainly in Guadalentin Basin Murcia-Spain. And in Novij Saratov-Russia study sites. Gently sloping (2-6%) field sites is the following important class (Fig. 18) covering 18.2% of the study field sites. Such slope gradients have been measured in all study field sites. Moderately sloping areas (6-12%) have been described in 12.6% of the study field sites. Such slope gradients have been measured in all study sites except for Djanybek-Russia, Novij Saratov-Russia, and Konya Karapinar plain-Turkey. Strongly sloping areas (12-18%) have been found in all study sites except for Djanybek-Russia, Novij Saratov-Russia, and Konya Karapinar plain-Turkey, covering 9.3% of the total field sites. Moderately steep (18-25%) to steep (25-35%) slopes occupy 6.2% and 5.7% of the study sites, respectively. Such field sites have been identified in all study sites except for Djanybek-Russia, Novij Saratov-Russia, Boteti Area-Botswana, Zeuss Koutine-Tunisia, and Konya Karapinar plain-Turkey. Steep (35-60%) to very steep (>60%) slopes were measured in 10.8% and 10.9% of the study field sites, respectively. Such steep slopes have been mainly measured in the study sites of in Konya Karapinar plain-Turkey, Crete-Greece, Plateau-China, Santiago Island-Cape Verde, Secano Interior-Chile, and Zeuss Koutine-Tunisia.

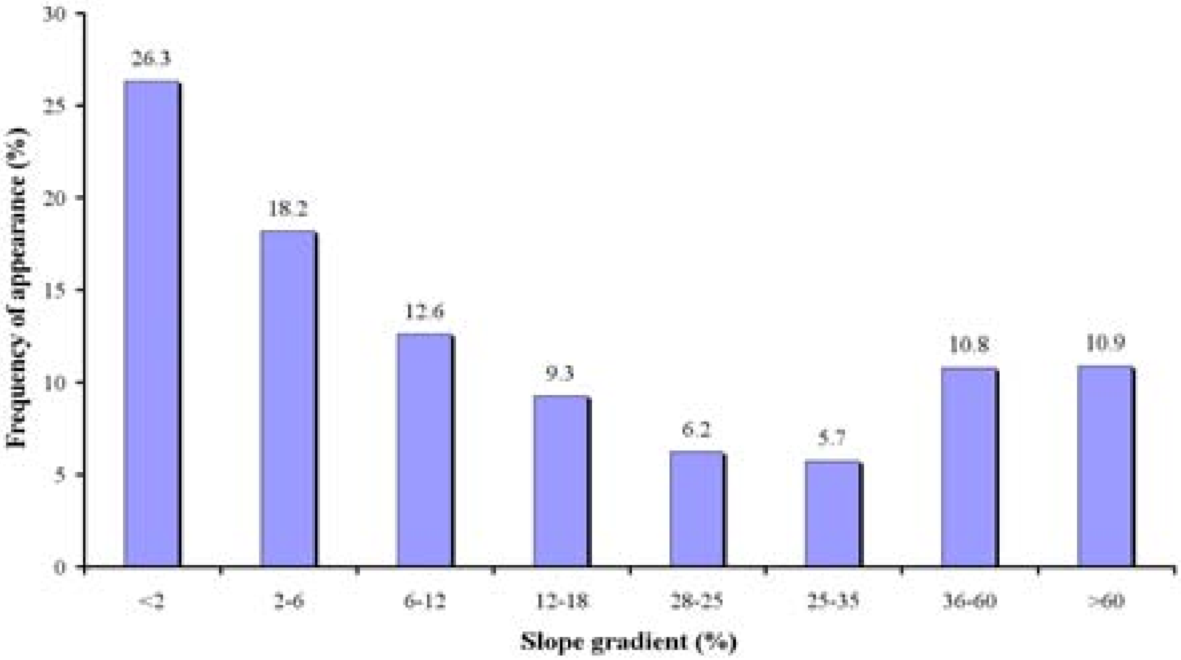

Fig. 21. Distribution of slope gradient classes defined in the study field sites

<u>Soil depth</u>

Soil depth can be considered as the most important soil indicator affecting desertification. Percentage vegetation cover of a soil surface under semi-arid climatic conditions is largely controlled by soil water storage capacity and therefore soil depth. Soil depth decrease due to soil erosion is a serious threat to the soil quality and productivity in hilly areas (Fig. 22). The effects of soil erosion on its productivity depend largely on the thickness and quality of the topsoil and on the nature of the subsoil. Most hilly soils are shallow or have some undesirable properties in the subsoil such as petrocalcic horizon, or bedrock (Fig. 22) that adversely affects yields. In either case, productivity will decrease as the topsoil gets thinner by erosion and undesirable subsoil is mixed into the topsoil by tillage.

Soil depth in the study field sites has been measured by using an auger or in existing cuts. The following classes have been distinguished: (a) very shallow, soil depth <15; (b) shallow, soil depth 15-30 cm; (c) slightly deep, soil depth 30-60 cm; (d) moderately deep, soil depth 60-100 cm; (e) deep, soil depth 100-150 cm; and (f) very deep, soil depth >150 cm.

Fig. 22. Deep soil formed on marl deposits (left) and shallow soil formed on limestone (right)

Soil depth has been measured in 1577 field sites, corresponding to 17 study sites (Table 3). The obtained results show a variety of soil depths depending on the type of parent material, slope gradient, and degree of erosion (Fig. 23). Many of the study fields have very deep soils (depth>150 cm), covering over 22.6% of the total sites. Such soils have been mainly found in Plateau-China and Nestos Basin Maggana-Greece and in some cases in the study sites of Crete-Greece, Santiago Island-Cape Verde, Eskisehir Plain-Turkey, Rendina Basin Basilicata-Italy, Cointzio catchment-Mexico, and Zeuss Koutine-Tunisia. The next most important class of soil depth is slightly deep (depth 30-60 cm), covering 21.8% of the field sites. Such soils have been found in all studies sites except Plateau-China, and Nestos Basin Maggana-Greece. Moderately deep (depth 60-100 cm) and deep soils (100-150 cm) cover 12.7% and 15.7% of the study field sites, respectively. Such soils have been described in all study sites except Plateau-China, and Nestos Basin Maggana-Greece. Very shallow (depth <15 cm) to shallow (15-30 cm) soils have been found in several cases covering 11.2% and 16.0%, respectively. Such areas are highly degraded very sensitive to desertification and they are found in the study sites of Konya Karapinar plain-Turkey, Boteti Area-Botswana, Zeuss Koutine-Tunisia, Crete-Greece, Santiago Island-Cape Verde, Eskisehir Plain-Turkey, Mação-Portugal, Mamora Sehoul-Morocco, Cointzio catchment-Mexico, Gois-Portugal, and Guadalentin Basin Murcia-Spain.

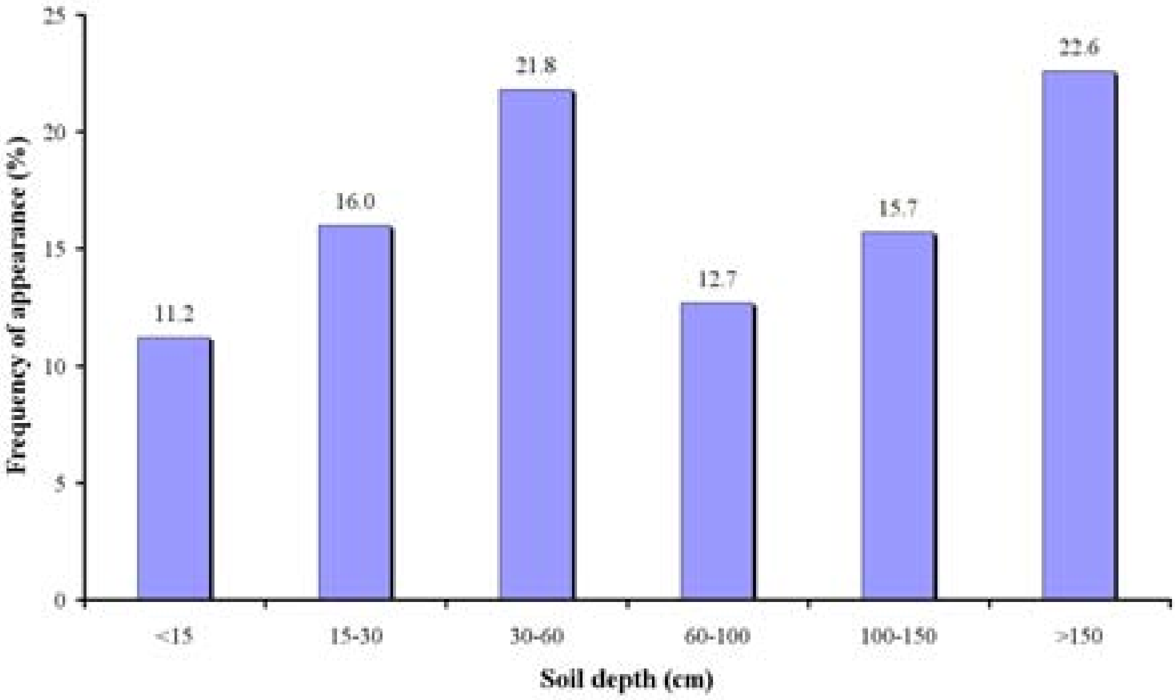

Fig. 23. Distribution of soil depth classes found in the study field sites

Soil texture

Soil texture is the relative proportion of sand, silt, and clay in a soil. Sand, silt and clay are the 2.0 to 0.05, the 0.05 to 0.002 and the less than 0.002 mm soil fractions, respectively. Soil texture greatly affects soil drainage, water holding capacity, soil temperature, soil erosion as well as fertility and plant productivity. Clay holds more water available for plant growth than sandy soils and the presence of water considerably modifies the heat requirements of the soil. Clay soils have poor drainage of excess water and may become waterlogged. Soil texture affects soil resistance to erosion. The coarser the soil texture, the smaller the active surface area of the soil particles, and the smaller is the resistance of the soil to erosion. Soils containing high amount of silt, such as those formed on marl deposits, are sensitive to crust formation generating high surface water runoff and sediment loss.

Soils have been classified according to their texture in classes, and each textural class had a given range of sand, silt and clay. The following 12 classes were designated: Sand (S), loamy sand (LS), sandy loam (SL), loam, (L), silt loam (SiL), silt (Si), clay loam (CL), sandy clay loam (SCL), silty clay loam (SiCL), clay (C), silty clay (SiC), and sandy clay (SC) (Fig 24). Four broad groups of classes are recognized: Sands, Silts, Clays and Loams. Sands contain at least 80% sand particles and 15% or less clay particles by weight. Silts contain at least 80% silt and 12% clay particles, respectively. Clays contain at least 35% of clay particles. Loams are mixtures of sand, silt and clay particles that exhibit the properties of those particles in equal proportions. Loam soils have the best combination of physical and chemical properties in terms of cultivation and crop growth.

Soil texture has been estimated in the field through the feel of a moist soil moulded between fingers and thumb. Also soil texture was quantitatively determined in the laboratory using the hydrometer method. The 12 textural classes were further grouped into 6 categories very coarse (S, LS), coarse (SL), medium (L, SiL, and Si), fine (Cl, SCL, and SiCL), fine (C, SiC and SC) and very fine soils having clay content greater than 70%.

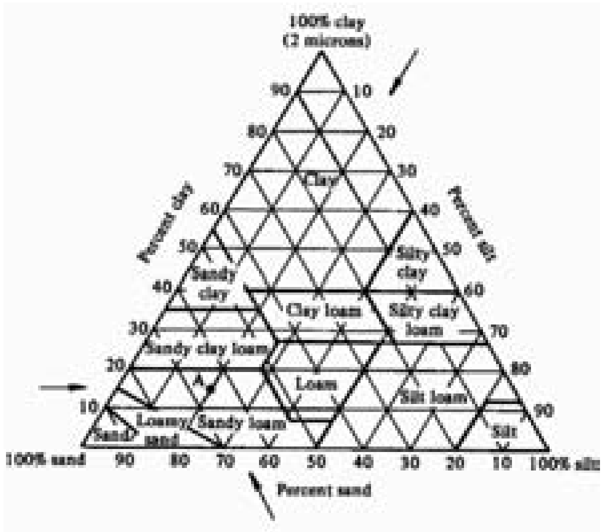

Fig. 24. The USDA textural triangle showing the limits of sand, silt and clay contents of the various textural classes

Soil texture has been determined in 1497 field sites, corresponding to 15 study sites (Table 3). The dominant textural classes were fine, covering 39.0% of the study field sites (Fig. 25). Such textural class has been found in all study field sites of Guadalentin Basin Murcia-Spain, and Djanybek-Russia, and in some cases in the rest of study sites except Plateau-China. The following important textural classes were fine, covering 28.7% of the study field sites. Such soil textural classes were found in all study field sites of Loess Plateau-China, and in some study fields of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Nestos Basin Maggana-Greece, Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Gois-Portugal, Cointzio catchment-Mexico, and Crete-Greece. Moderately fine textural classes were found in 14.2% of the study field sites located mainly in the field sites of Secano Interior-Chile, Nestos Basin Maggana-Greece, Boteti Area-Botswana, Konya Karapinar plain-Turkey, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Eskisehir-Turkey, Zeuss Koutine-Tunisia, Novij Saratov-Russia, Djanybek-Russia, Gois-Portugal, Cointzio catchment-Mexico, and Crete-Greece. Coarse and very coarse textural classes were found in some cases covering 4.6% and 10.6% of the study field sites, respectively. Such textural classes did not found in the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, Djanybek-Russia, Gois-Portugal, Cointzio catchment-Mexico, and Loess Plateau-China. Very fine textural classes were very limited, covering 2.9% of the study field sites and located in the study sites of

Boteti Area-Botswana, Konya Karapinar plain-Turkey, Gois-Portugal, Cointzio catchment-Mexico, and Eskisehir-Turkey.

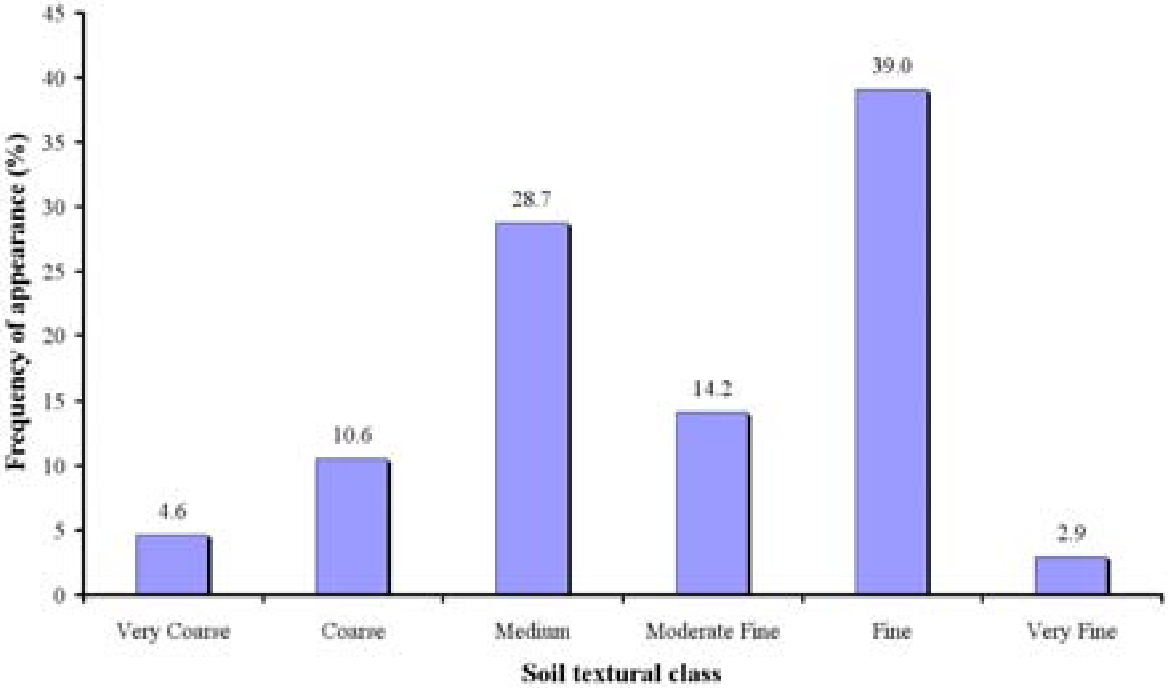

Fig. 25. Distribution of soil textural classes measured in the study field sites

Water storage capacity

Soil water storage capacity corresponds to the amount of water that can be stored into the soil. It refers to the amount of water that is available for the plant growth. If such water content becomes too low, plants will become stressed. The plant available moisture storage capacity of a soil provides a buffer, which determines the plant's capacity to withstand dry conditions. The terms field capacity, and wilting point are used here. Field capacity refers to the soil situation when excess water has drained out due to gravitational pull. Permanent wilting point refers to the soil situation when a plant wilts beyond recovery due to a lack of water in the soil. Available water in this project was considered as the amount of the water held in a soil between field capacity and permanent wilting point. The following classes of soil water storage capacity (SWSC) have been defined: (a) SWSC<50 mm, (b) SWSC=50-100 mm, (c) SWSC=100-200 mm, (d) SWSC=200-300 mm, and (e) SWSC>300 mm.

Table 3 shows soil water storage capacity that has been determined for 1309 field sites, corresponding to 13 study sites. Fig. 26 shows the majority of the study field sites that had very low (<50 mm) and low (50-100 mm) SWSC indicating high vulnerability to desertification under semi-arid and dry sub-humid climatic conditions, covering 23.1% and 25.1% (Fig. 26) of the study field sites, respectively. Such fields sites were found in some cases in all study sites but all the study field sites of Secano Interior-Chile, Mamora Sehoul-Morocco, and Santiago Island-Cape Verde had only these two classes of SWSC. Moderate SWSC values were found in 21.3% of the study field sites located mainly in all the study sites except those mentioned above with low SWSC. High (200-300 mm) and very high (>300 mm) SWSC classes cover 19.6% and 10.8% of the study field sites, respectively. Such classes of SWSC were measured in all study field sites except for Eskisehir-Turkey, Mamora Sehoul-Morocco, Secano Interior-Chile, and Nestos Basin Maggana-Greece.

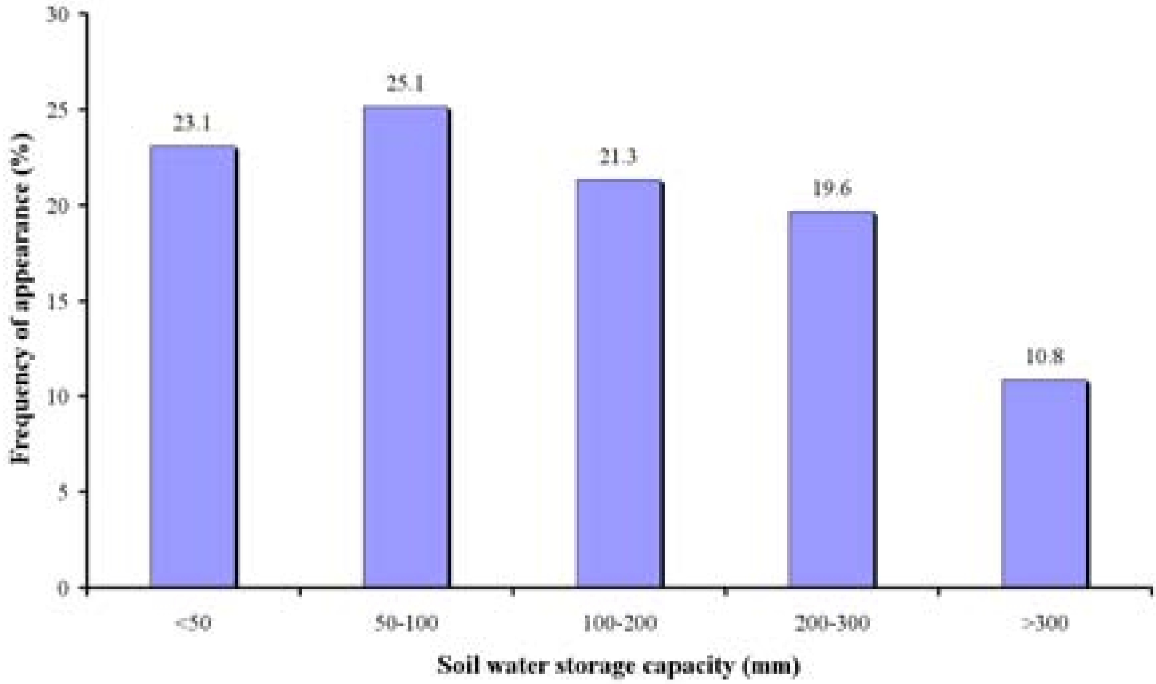

Fig. 26. Distribution of soil water storage capacity classes measured in the study field sites

<u>Exposure of rock outcrops</u>

Exposure of rock outcrops refers to a mixed area that consists of spots of exposures of bedrock and soil. A type of land having little or no soil supported vegetation. Usually such areas have been greatly degraded due to soil erosion and they are mainly characterized as critical areas to desertification. Such conditions are very common in soils formed on consolidated parent materials such as limestone, sandstone, lava, etc. (Fig 27).

Fig. 27. Shallow highly degraded soils, with the bedrock exposed in patches on the soil surface (rock outcrops), formed on acid igneous rock (left) and limestone (right)

Rock outcrops have been defined for the purpose of the DESIRE project according to the percentage cover in four classes: (a) rock outcrops>60%, (b) rock outcrops = 30-60, (c) rock outcrops = 10-30%, (d) rock outcrops = 1-10%, and (e) none.

As Table 3 shows, data for rock outcrops have been defined in 1056 field sites, corresponding to 12 field sites. As Fig. 28 shows most of the field sites were free of rock outcrops covering 57.8% of the study field sites corresponding to all study sites. The following important class was this with rock outcrops exposed in an area of 1-10% of the study field, covering 27.5% of the study field sites. Such cases were found in all study sites except for Novij Saratov-Russia. The classes of rock outcrops 10-30%, 30-60%, and >60% were found in few cases in the study field sites (Fig. 28) of Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Cointzio catchment-Mexico, Boteti Area-Botswana, and Guadalentin Basin Murcia-Spain.

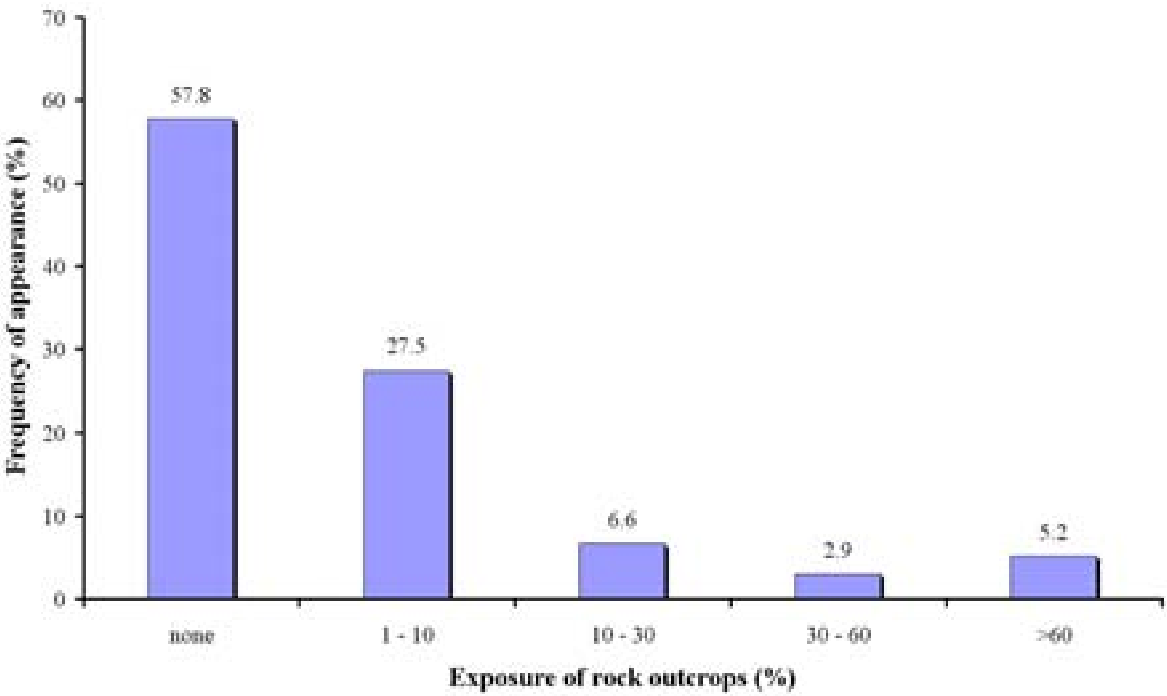

Fig. 28. Distribution of rock outcrops classes measured in the various study field sites

Organic matter in surface horizons

Soil organic matter represents a key indicator for soil quality, both for agricultural functions (i.e. production and economy) and for environmental functions (e.g., carbon sequestration and air quality). Soil organic carbon is a major indicator influencing physical, chemical and biological soil parameters. Aggregation and stability of soil structure increase with organic matter content. These in turn increase infiltration rate and available water capacity of the soil, as well as resistance against erosion by water and wind. The development of agriculture has caused a large loss of soil organic matter. Global climatic change may have a similar effect. Apart from climatic factors (mainly drought and temperature), the main processes causing losses in soil C are: cultivation of undisturbed land, soil erosion, mineralization of organic matter, leaching of dissolved organic and inorganic substances. Soil erosion by water or wind, represents the most important soil organic matter decline process. There are several land management practices for soil carbon conservation, such as reduced or zero tillage, application of biosolids (manure, crop residues, and compost), cover and deep-rooting crops, conservation of grassland and woodland, improved rotations, fertilization and irrigation.

Soil organic matter has been determined in the study field sites by chemical analysis of soil samples of fine earth (materials pass through a 2 mm sieve). The dichromate method has been used for organic carbon determination. The following classes have been defined: (a) high organic matter content OM>6%); (b) moderate, OM=2.1-6.0%; (c) low, OM=2.0-1.1%; and (d) very low, OM<1.0.

Data for the organic matter content in the soil surface horizon have been collected in 1136 field sites, corresponding to 14 study sites (Table 3). As Fig. 29 shows, the majority of the study soils had low (2.0-1.1%) to very low (<1%) organic matter content, covering 40.0% and 34.9% of the study field sites. Such amounts of organic matter content were found in all study sites except for Novij Saratov-Russia. Moderate (2.1-6.0%) amounts of organic matter was found in 22.2% of the study sites corresponding to all study sites except for Guadalentin Basin Murcia-Spain, and Zeuss Koutine-Tunisia which had lower amounts. High amounts of organic matter in surface horizon have been measured in very few field sites of Boteti Area-Botswana, Cointzio catchment-Mexico, and Mamora Sehoul-Morocco. These field sites correspond to forested land.

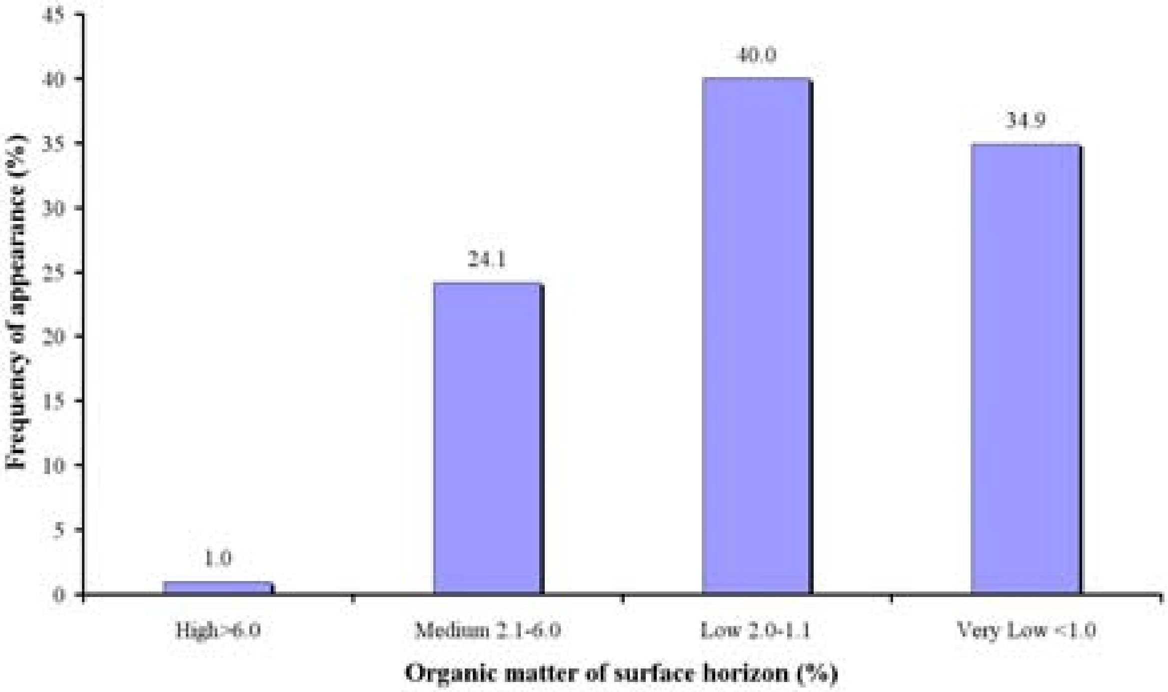

Fig. 29. Distribution of soil organic matter content in the surface soil horizon measured in the study field sites

<u>Degree of soil erosion</u>

The UNCCD has defined soil erosion as one of the main causes of land degradation and desertification. The erosion risk depends on several factors, such as slope gradient, vegetation cover, and soil type and rain erosivity. Soil erosion can be quantitatively estimated in experimental fields or by applying soil erosion models such as the PESERA model to be used in WB5 of this project. Furthermore, soil erosion can be qualitatively estimated by observing certain erosion features on the soil surface. A qualitatively measurement of soil erosion is the degree of erosion as it assessed in soil surveys. Soil erosion in this work package of the DESIRE project has been qualitatively determined by estimating the degree of soil erosion using the following soil surface characteristics: (i) the presence or not of the A-horizon, (ii) the existence and percentage of subsurface horizons, (iii) the degree of exposure of the parent material on the soil surface, and (iv) the presence of erosional gullies. Five classes of degree of erosion have been distinguished, very severe, severe, moderate, slight, and no erosion. The degree of soil erosion has been described using the following table.

Erosion class	Description
no erosion	no erosion features are present in the soil surface
Slight	Parts of the A horizon have been eroded, so that usually less than 20% of the initial A horizon presents current scattered spots of erosion.
Moderate	Soils that present an intricate pattern of current subsurface horizons ranging on the average from 20% to 50% on the original A horizon.
Severe	Soils that shows an intricate pattern of subsurface horizons ranging from 50% to 80% of the original A horizon. In most areas of this class erosion, the parent material is exposed at the surface.

Very severe	Soils that have lost more than 80% of the A-horizon and some or all the deeper horizons throughout most of the area. Original soil can be identified only in spots. Some areas may be smooth, but most have an intricate pattern of gullies and the parent material is exposed at the soil surface.

Some typical examples of soil surfaces with different degree of soil erosion are given in Fig. 30.

Fig. 30. Soil surfaces with slight (left), moderate (center) and very severe (right) degree of soil erosion

As Table 3 shows the degree of erosion has been described in 1221 field sites, corresponding to 16 study sites. As Fig 31 shows, the dominant class of degree of soil erosion is moderate erosion covering 34.7% of the study field sites. Such degree of soil erosion has been described in all study field sites of Konya Karapinar plain-Turkey and in some cases in all the rest study sites. The next important class is severe erosion covering 21.4% of the study field sites. Severe erosion has been described in all field sites of Novij Saratov-Russia, and in some cases in the rest of study sites except for Konya Karapinar plain-Turkey, and Djanybek-Russia. Very severe erosion has been found in 12.0% of the study field sites, corresponding to same cases for the study sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Cointzio catchment-Mexico, Guadalentin Basin, Loess Plateau-China, , Rendina Basin Basilicata-Italy, Murcia-Spain, and Crete-Greece. No to slight erosion have been estimated in 14.0% and 17.9% of the study field sites, respectively. Such degree of soil erosion has been defined mainly in plain areas in which the main process of desertification is soil salinization or in sloping forested areas fully covered with vegetation. No to slight erosion has been described in some of the field sites of the following study sites: Secano Interior-Chile, Boteti Area-Botswana, Santiago island-Cape Verde, Mamora Sehoul-Morocco, Gois-Portugal, Loess Plateau-China, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Cointzio catchment-Mexico, Rendina Basin Basilicata-Italy, and Crete-Greece.

Electrical conductivity

Salt content of the soil can be assessed by measuring the electrical conductivity in a saturated soil paste. Salinization is a major process that causes salt accumulation in soils and it is related to climate, physiography, and irrigation. The climate acts directly through high evaporation rates, and indirectly as the driving force behind soil salinization associated with irrigation. A distinction can be made between primary and secondary Salinization processes. Primary salinization involves accumulation of salts through natural processes such as physical and chemical weathering and transport processes from salty geological deposits or groundwater. Secondary Salinization is caused by human interventions such as inappropriate irrigation practices, use of salt-rich irrigation water and/or poor drainage conditions.

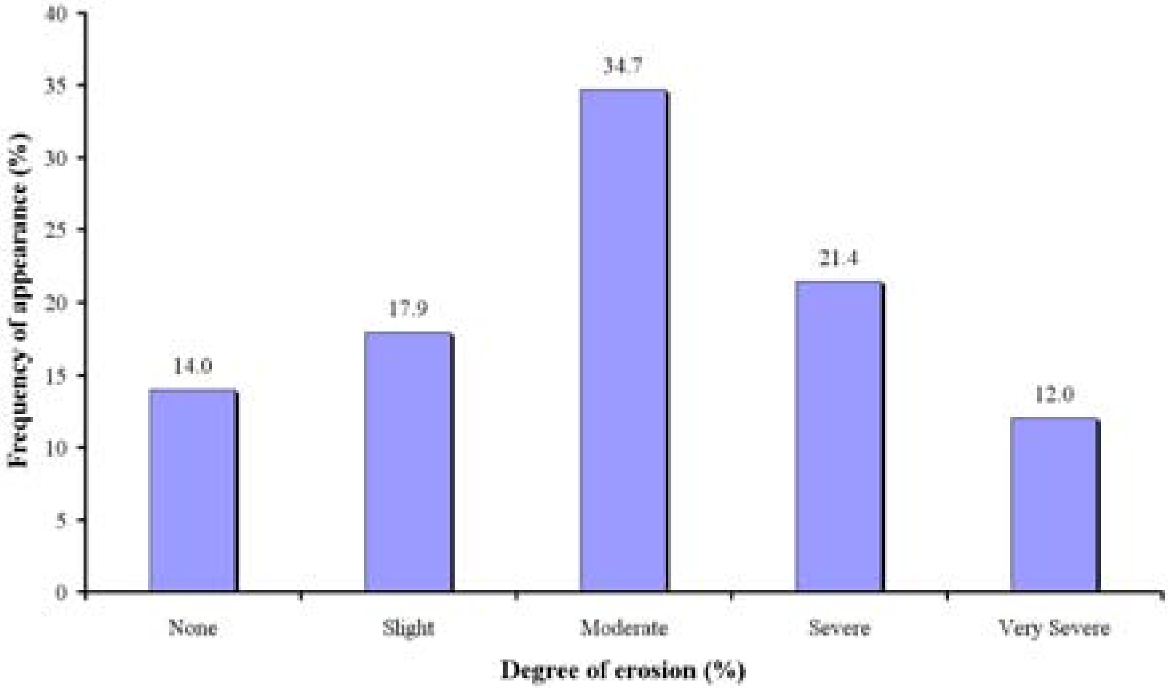

Fig. 31. Distribution of degree of soil erosion estimated in the study field sites

Electrical conductivity (EC) in the study field sites has been measured directly in the field using an electrical conductivity-probe set (Fig. 32) for salinity measurements or in the laboratory on a saturated paste. The following classes of soil electrical conductivity have been used for the DESIRE project: (a) free of salts, EC< 2 dS m^{-1}; (b) slightly affected soils, EC = 2 to 4 dS m^{-1}; (c) moderately affected soils, EC = 4 to 8 dS m^{-1}; (d) highly affected soils, EC = 8-15 dS m^{-1}; and (e) very highly affected soils, EC>15 dS m^{-1}.

Fig. 32. Soil with high electrical conductivity (left) due to high salt concentration and an electrical conductivity-probe used for measuring it (right)

Soil electrical conductivity has been measured in 258 field sites, corresponding to the 5 following study sites (Table 3): Nestos Basin Maggana-Greece, Boteti Area-Botswana, Secano Interior-Chile, Mamora Sehoul-Morocco, Novij Saratov-Russia, Djanybek-Russia, and Crete-Greece. As Fig. 33 shows, the majority of the study field sites (53.5%) had a moderate (4-8 dS m^{-1}) soil electrical conductivity corresponding to all above mentioned study sites except for Boteti Area-Botswana. Highly salt affected soils with an electrical conductivity (8-15 dS m^{-1}) have been found in

22.9% of the study field sites. Such values of electrical conductivity have been measured in all the above mentioned study sites. Slightly affected soils have been found in 14.7% of the study field sites, corresponding to the above study sites except for Djanybek-Russia, and Boteti Area-Botswana sites. Soils free of salts have been found in 5% of the study field sites located in the study sites of Greece. Very highly salt affected soils have been found in few cases (3.9% of the study field sites) in Nestos Basin Maggana-Greece, and Boteti Area-Botswana sites.

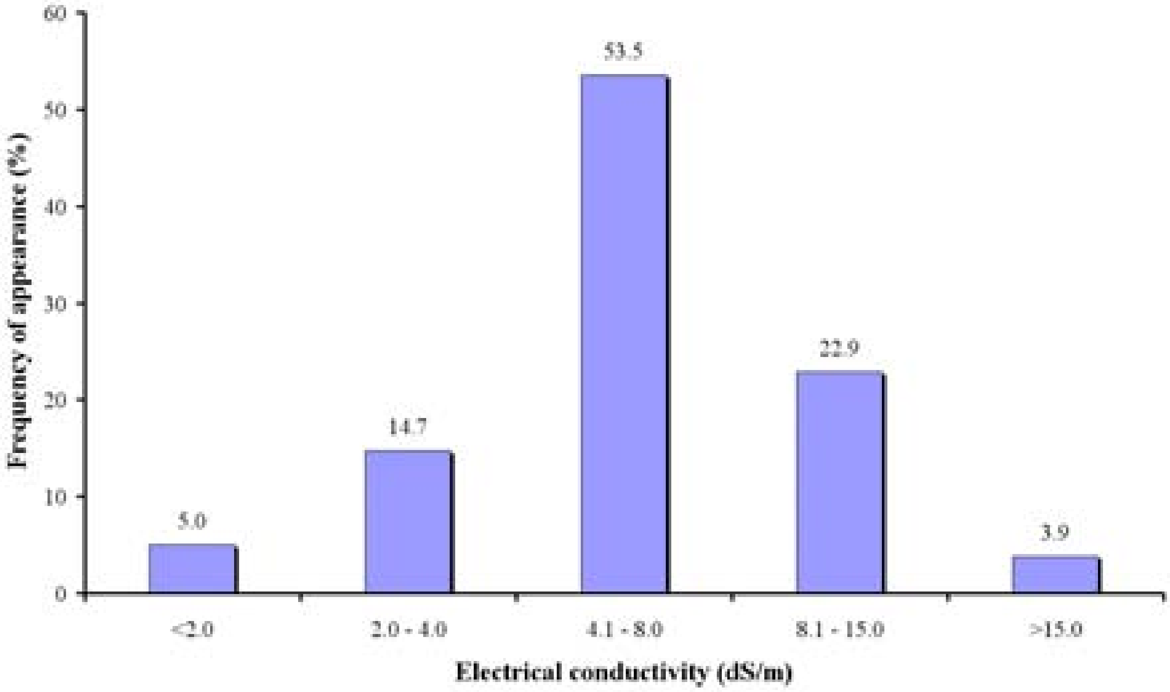

Fig. 33. Distribution of soil electrical conductivity classes measured in the various study field sites

2.4 Indicators related to vegetation

Vegetation is a crucial factor which affects soils in all its dynamics including erosion control, water redistribution over and within the soil and the microbial activity. Surface water runoff is greatly controlled by vegetation which can be readily altered in hilly areas depending on climatic conditions and the period of the year. By its microbial activity affects soil aggregation especially in the surface soil horizon and water infiltration. In areas with annual precipitation of less than 300 mm and a high evapotranspiration rate, the soil water available to the plants is reduced drastically and the soil remains relatively bare favoring overland water flow whenever rainfall events do occur. Key indicators related to vegetation for defining desertification risk in the DESIRE project have been considered the following: (a) major land use type, (b) vegetation cover type, and (c) vegetation cover, and (d) deforested area.

Major land use

The land use type can be separated into two categories: (a) major land use, and (b) vegetation cover type or land utilization type. The major land use is a broad category defining general land use types such as agriculture, pastures, forests, recreation areas, etc. The land utilization type is a more detailed subdivision of the previous category defining the specific land use type such as cereals, olive groves, pine forests, etc. Major land use has been defined by: (a) simple field observation, (b) interpretation of aerial photographs or remote sensing images. The following categories of major land have been distinguished in the DESIRE project: agriculture, pasture, shrubland, forest, mining area, recreation area, and urban area.

As Table 4 shows, major land use types have been identified in 1324 field sites, corresponding to 16 study sites. The prevailing major land use type described in the study field sites was agriculture, covering 50.2% of the total sites (Fig 34). Such land use has been found in all study field sites of Rendina Basin Basilicata-Italy, and Novij Saratov-Russia, and in some cases in all the other study sites. Pasture land was the next important major land use in covering 24.9% of the study field sites. Such land use has been identified in all study sites except for Rendina Basin Basilicata-Italy, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, Cointzio catchment-Mexico, Gois-Portugal, and Mação- Portugal. Field sites under forest have been found in 11.4% of the total sites corresponding mainly to the following study sites of Rendina Basin Basilicata-Italy, Cointzio catchment-Mexico, Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Loess Plateau-China, Gois-Portugal, nd Eskisehir-Turkey. Shrubland and other land uses have been identified in 5.3% of the study field sites found mainly in Guadalentin Basin Murcia-Spain, Gois-Portugal, and Mação- Portugal-Portugal study sites. Other land uses corresponds to areas under specific regulations such as military installations, settlement place, etc.

Table 4. Number of field sites in which the indicators related to vegetation was recorded in the filled questionnaires

site no	Study site	Number of field sites described for the indicator			
		Major land use	Vegetation cover type	Vegetation cover	Deforested area
1	Nestos Basin, Maggana, Greece	-	-	-	-
2	Rendina Basin, Basilicata, Italy	30	-	-	-
3	Secano Interior, Chile	28	28	28	-
4	Gois, Portugal	30	30	30	30
5	Mação, Portugal	31	31	31	31
6	Loess Plateau, China	150	-	-	-
7	Boteti Area, Botswana	52	49	49	47
8	Cointzio watershed, Mexico	87	54	87	20
9	Djanybek, Russia	69	69	69	69
10	Eskisehir, Turkey	70	70	70	70
11	Konya, Karapinar plain, Turkey	74	74	74	74
12	Santiago Island, Cape Verde	103	103	103	-
13	Novij, Saratov, Russia	84	84	84	62
14	Zeuss-Koutine, Tunisia	120	120	120	-
15	Mamora/Sehoul, Morocco	120	120	120	-
16	Guadalentin Basin, Murcia, Spain	121	121	121	-
17	Crete, Greece	155	155	155	-
	TOTAL	1324	1108	1141	403

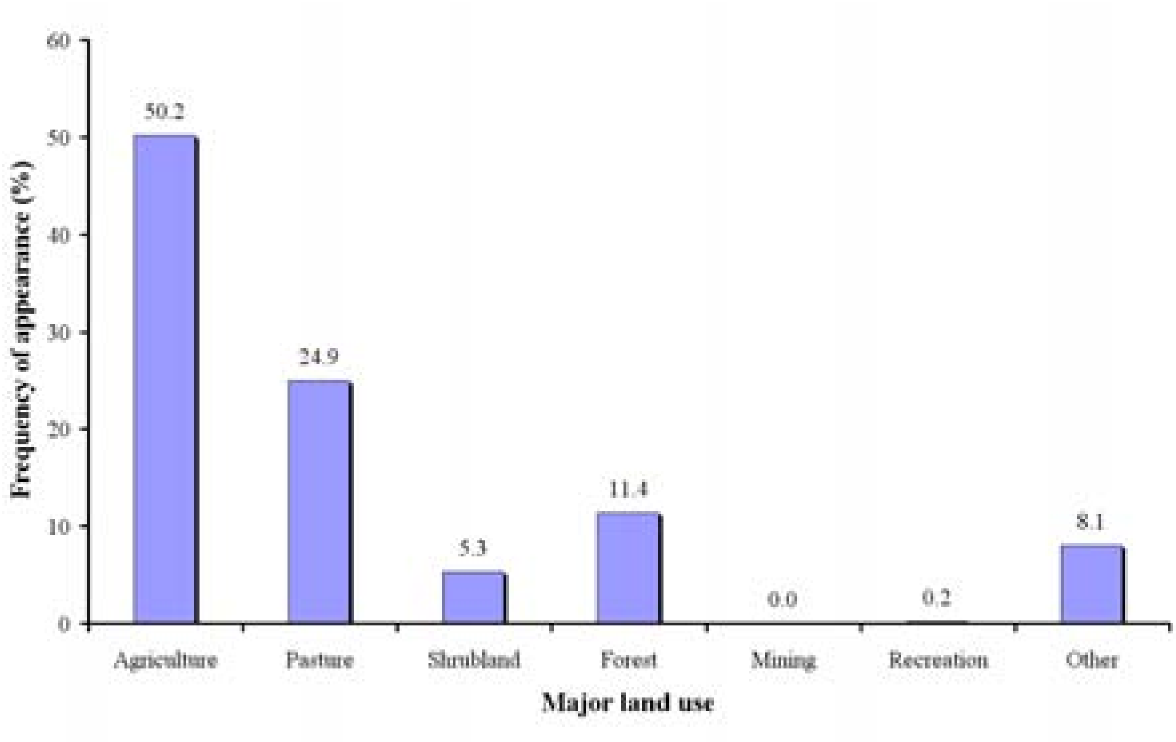

Fig. 34. Distribution of major land uses identified in the various study field sites

Vegetation cover type

Vegetation cover type defines the specific characteristics of land uses such as vines, olives, cereals, pine forest, oak forest, etc (Fig. 35). Extensive Mediterranean areas cultivated with rainfed crops such as cereals, vines, almonds and olives are mainly confided to hilly lands with shallow soils very sensitive to erosion. These areas become vulnerable to erosion and desertification because of the decreased protection effect of the vegetation cover from raindrop impact during heavy rains. Soil erosion measurements conducted along the Mediterranean Europe and Portugal during the execution of MEDALUS projects have shown that under the existing land management practices vines generate the highest amount of runoff and sediment loss followed by eucalyptus, cereals, shrubland and olive groves in a decreasing rate. Olives present a particularly high adaptation and resistance to long term droughts and under semi-natural conditions support a remarkable diversity of flora and fauna even higher than some natural ecosystems, protecting hilly areas from erosion and desertification.

Fig 35. Examples of vegetation cover type corresponding to agriculture-olives (left) and forest-pines (right)

Land use types have been identified in the study field sites by: (a) simple field observations, and (b) aerial photographs or remote sensing images interpretation. The following categories of plant cover have been distinguished: (a) agricultural land uses: cereals, olives, vines, almonds, oranges, vegetables, cotton, bare land, etc.; and (b) forest areas: Mixed Mediterranean Machia/evergreen forest, Mediterranean machia, permanent grassland, annual grassland, deciduous forest, pine forest, and evergreen forest (except pines), etc.

As Table 4 shows, vegetation cover type has been identified in 1108 field sites, corresponding to 15 study sites. The dominant agricultural land use identified in the study field sites was cereals, covering 36.4% of the total sites (Fig. 36). Such land use type has been mainly described in the study sites of Boteti Area-Botswana, Konya Karapinar plain-Turkey, Santiago island-Cape Verde, Mamora Sehoul-Morocco, Eskisehir-Turkey, Gois-Portugal, Cointzio catchment-Mexico, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, and Djanybek-Russia. Olive groves and vineyards have been found in about equal number of field sites (15.9%, 17.1%, respectively). Such land uses have been identified in all study sites except from Boteti Area-Botswana, Konya Karapinar plain-Turkey, Gois-Portugal, Santiago Island-Cape Verde, Novij Saratov-Russia, and Djanybek-Russia sites. Cotton has been described in 9.2% of the study field sites corresponding mainly to the study sites of Boteti Area-Botswana, Konya Karapinar plain-Turkey, Mamora Sehoul-Morocco, Eskisehir-Turkey, Guadalentin Basin Murcia-Spain, and Djanybek-Russia. Other land uses such as almonds, oranges, vegetables, etc. have been found in few cases, covering 2.8%, 3.1%, and 6.8% of the study field sites, respectively, corresponding mainly to the study sites of Secano Interior-Chile, Boteti Area-Botswana, Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, and Crete-Greece.

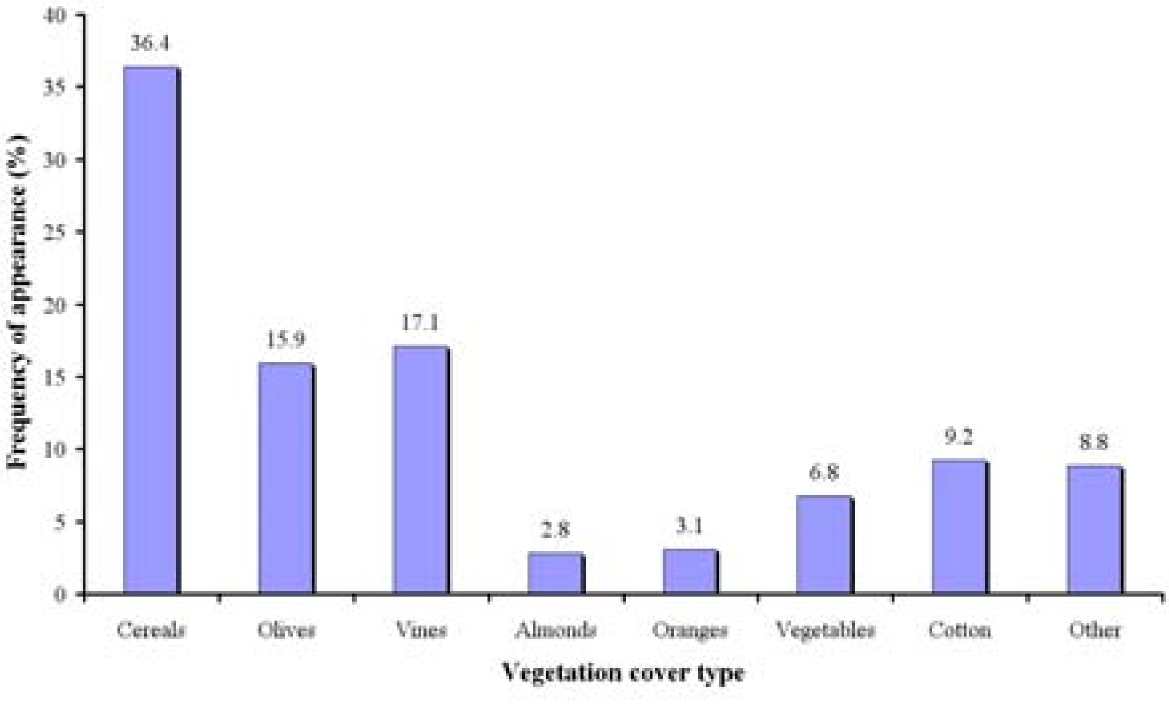

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Fig. 36. Distribution of land use types identified in agricultural areas of the study sites

Vegetation cover

The percentage of soil which is covered by green vegetation is defined as plant cover. Leaf area index (LAI) is an alternative expression of the term plant cover which gives the area of leaves in m² corresponding to an area of one m² of ground. Many studies have demonstrated that in a wide range of environments, both runoff and sediment loss decrease exponentially with increasing percentage of plant cover. Forest vegetation reduces significantly summer soil surface temperatures and it is necessary for the regeneration of many forest species in the Mediterranean. A vegetation cover 45-50% is considered as critical value since above this value soils are adequately protected from raindrop impact and soil erosion is significantly reduced.

Vegetation cover has been measured in the field by assessing the percentage of the ground that it is covered by the existing annual or perennial vegetation. Aerial photographs or satellite images has been also used for measuring vegetation cover of extensive areas. Four classes of vegetation cover have been used for the purpose of this project: (a) vegetation cover <10%, (b) vegetation cover =10-25%, (c) vegetation cover = 25-50%, (d) vegetation cover = 50-75%, and (e) vegetation cover >75%.

Vegetation cover has been measured in 1141 field sites, corresponding to 15 study sites (Table 4). As Fig. 37 shows, field sites with vegetation cover classes greater than the critical value of 50% were found in 28.1% (cover 50-75%) and in 19.2% (cover >75%) of the study field sites (Fig. 37). Such well vegetated field sites correspond mainly to the study sites of Secano Interior-Chile, Boteti Area-Botswana, Santiago island-Cape Verde, Gois-Portugal, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, Eskisehir-Turkey, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, Djanybek-Russia, Crete-Greece, and Mação-Portugal. Vegetation cover classes <10%, 10-25%, and 25-50%, which are less than the critical value of 50%, have been measured in a significant number of field sites, covering 17.4%, 17.1%, and 118.1% of the total sites (Fig. 37). Such poorly vegetated sites have been found in all study sites except for Eskisehir-Turkey site. Field sites almost bare (vegetation cover <10%) have been mainly described in the study sites of Secano Interior-Chile, Boteti Area-Botswana, Santiago island-Cape Verde, Gois-Portugal, Cointzio Catchment-Mexico, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Crete-Greece, and Zeuss Koutine-Tunisia. Most of these field sites have so much eroded that the consolidated rock has been exposed on the soil surface generating probably high water runoff rates but low soil loss since there is no soil left to be eroded (Fig. 38). Of course there cases in which vegetation has been cleared for installing a new plantation creating very adverse conditions for soil erosion, land degradation and desertification (Fig. 38).

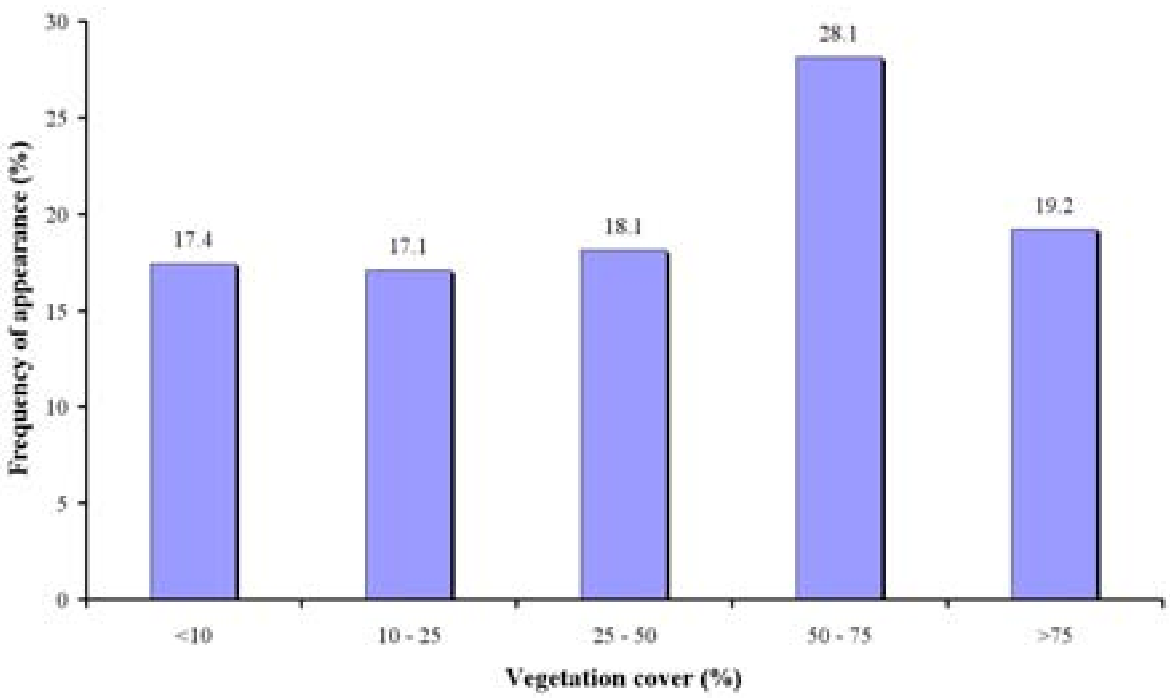

Fig. 37. Distribution of vegetation cover classes identified in the study field sites

 

Fig. 38. Areas with poor vegetation cover (<10%) in which soil erosion rates are low since bedrock has been exposed (left) or very high since vegetation has been cleared for new plantation exposing the soil to the raindrop impact (right)

__Deforested area__

Large scale deforestation of semiarid and dry sub-humid areas accompanied by intensive cultivation and overgrazing resulted in accelerated erosion and the formation of badlands with very shallow soils (Fig. 39a). Such areas are very sensitive to land degradation and desertification. Deforested area represents an important indicator for addressing political measures for protecting natural vegetation and combating desertification. It is defined as the total deforested surface annually expressed as a percentage of the total land surface. Such data are available for forested areas for different periods and territory levels from different organizations such as FAO, EUROSTAT, ISTAT, CFS, etc. This indicator is measured by using a combination of satellite-based earth observation and intensive field data collection to estimate deforestation process on a certain territory. Such data have been provided mainly from the national forestry departments.

 

Fig. 39a. Examples of deforested area to be used for pasture (left) and planting vines (right)

The following four classes of deforestation have been used: (a) low, <1.5 % of total deforested surface/total territorial surface/per year; (b) moderate, 1.5-2.5 % of total deforested surface/total territorial surface/per year; (c) high, 2.5-3.5 % of total deforested surface/total territorial surface/ per year; (d) very high, >3.5 % of total deforested surface/total territorial surface/ per year.

As Table 4 shows, data for deforested areas have been collected in 403 field sites, corresponding to 9 study sites. As Fig. 39b shows, the dominant class of deforestation is low for the study field sites covering 84.9% of the total sites. Low deforested rate has been measured in all field sites of Konya Karapinar plain-Turkey, Novij Saratov-Russia, Djanybek-Russia, and in most of the cases in Mação-Portugal, and Boteti Area-Botswana study sites. Moderate to high rate of deforestation have been identified in few field sites in Mação-Portugal, and Boteti Area-Botswana.

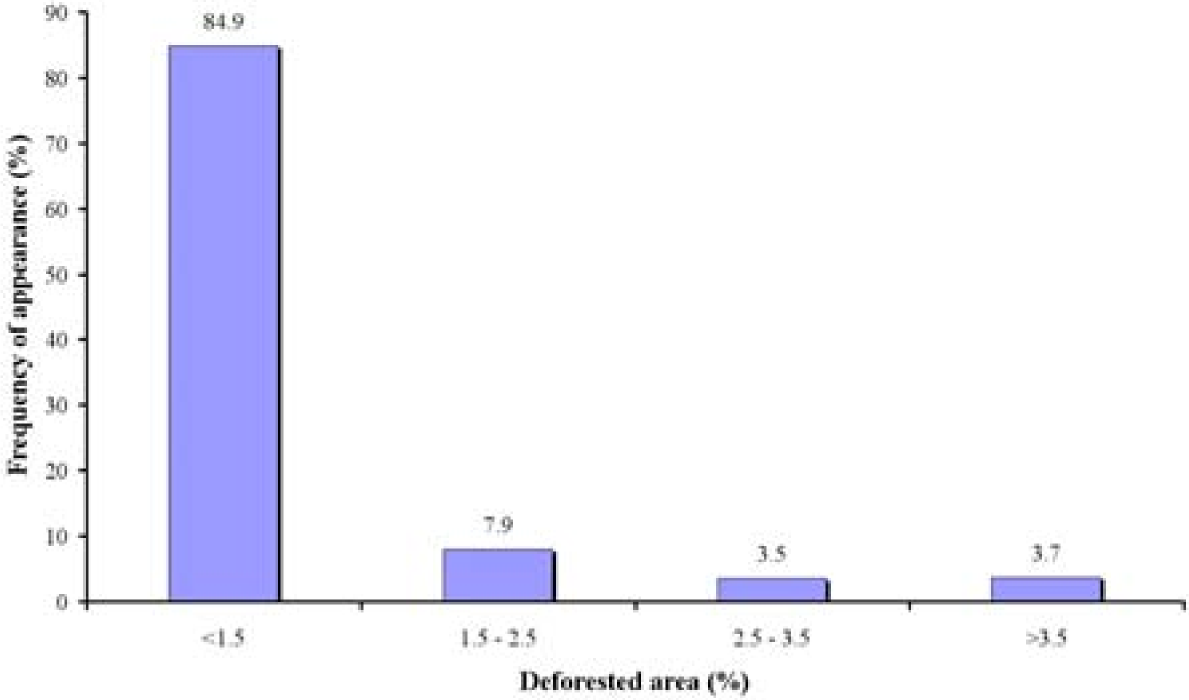

Fig. 39. Distribution of deforested area classes expressed as a percentage of land deforested over the total land forested surface per year

2.5 Indicators related to water runoff

Vegetation and land use are clearly important factors controlling the intensity and the frequency of overland flow and surface water erosion. Extensive deforestation followed by overgrazing or cultivation with rainfed crops usually results in decreased soil protection by vegetation cover, which reduces effective rainfall intensity, and in the reduction of infiltration rate due to degradation of soil structure and crust formation favoring surface water runoff and sediment loss. High t quantities of water runoff and sediment loss represents a serious hazard for land degradation and desertification in the study field sites, bringing about large reductions in vegetation growth, siltation of water courses, flooding of alluvial planes leaving even bigger areas under the threat of flood risk, and filling of valleys and reservoirs. Coastal zones are particularly prone to such devastating processes. Littoralisation accentuates the process of increased surface water runoff mainly through the artificial infrastructure cover that reduces water infiltration into the soil and disturbs the natural ecosystem. The following indicators related to surface water runoff have been considered in this project: (a) drainage density, (b) flooding frequency, and (d) impervious surface area.

Drainage density

Drainage density is defined as the total length of the streams in a drainage basin divided by the area of the basin. Climate affects drainage density both directly and indirectly. The amount and the type of precipitation influence directly the quantity and character of runoff. In areas where precipitation comes largely as thunder showers a large percentage of the rainfall will run off immediately and more surface drainage lines will be formed. Furthermore, climate affects indirectly drainage density by the amount and kind of vegetation growing affecting surface water runoff. Drainage density is greatly affected by the infiltration capacity of the mantle rock or bedrock. It is commonly observed that drainage lines are more numerous over impermeable materials than over permeable ones. Drainage density is also affected by the initial relief or the vertical distance from the initial upland flats to the levels of adjacent graded valleys. In practice the necessary material to carry out this measurement is often not available, and only quantitative estimates can be made.

Drainage density (DD) has been measured for drainage basins in which field sites have been located. That means several study sites had the same value for drainage density. This indicator has been measured by using the most detailed material available such as topographic maps, aerial photographs, and satellite images. As Fig 40 shows, the length of drainage streams was measured and was divided by the total surface area of the basin. The following classes of drainage density have been used: (a) coarse, DD<5 km length per km^2 area; (b) medium, DD=5-10 km km^{-2}; (c) fine, DD=10-20 km km^{-2}; and (d) very fine, DD>20 km km^{-2}.

Fig. 40. Example of measuring drainage density on a basin scale

As Table 5 shows, drainage density has been measured in 911 field sites, corresponding to 11 study sites. The dominant class of drainage density class is coarse (DD<5 km km^{-2}), covering 39.5% (Fig. 41) of the total study field sites, corresponding to Secano Interior-Chile, Boteti Area-Botswana, Santiago Island-Cape Verde, Eskisehir-Turkey, Zeuss Koutine-Tunisia, Mamora, Sehoul-Morocco Novij Saratov-Russia, Cointzio Catchment-Mexico, and Crete-Greece study sites. The next important class of drainage density in the study field sites was fine (10-20 km km^{-2}), covering 33.4% of the total fields (Fig. 41). Such drainage density is prevailing in Guadalentin Basin Murcia-Spain, and Eskisehir-Turkey, and in some cases in Santiago Island-Cape Verde, and Crete-Greece sites. The next important the frequency of appearance of medium (DD=5-10 km $km^{-2)}$ and very fine (DD>20 km km^{-2}) density classes were found in some cases covering 15.7% and 11.4% of the total study sites. Such drainage density classes were found in the study sites of Boteti Area-Botswana, Cointzio Catchment-Mexico, Santiago Island-Cape Verde, Novij Saratov-Russia, and Crete-Greece.

Table 5. Number of field sites in which the indicators related to water runoff was recorded in the filled questionnaires

site no	Study site	Number of field sites described for the indicator		
		Drainage Density	Flooding Frequency	Impervious surface area
1	**Rendina Basin, Basilicata, Italy**	-	-	-
2	**Mação, Portugal**	-	-	-
3	**Loess Plateau, China**	-	-	-

4	Gois, Portugal	-	-	-
5	Nestos Basin, Maggana, Greece	-	30	-
6	Boteti Area, Botswana	14	7	28
7	Secano Interior, Chile	28	-	28
8	Konya, Karapinar plain, Turkey	-	-	74
9	Mamora/Sehoul, Morocco	120	-	0
10	Djanybek, Russia	29	69	29
11	Cointzio watershed, Mexico	67	-	67
12	Eskisehir, Turkey	70	-	70
13	Novij, Saratov, Russia	84	38	84
14	Santiago Island, Cape Verde	103	-	103
15	Zeuss-Koutine, Tunisia	120	-	120
16	Guadalentin Basin, Murcia, Spain	121	-	121
17	Crete, Greece	155	114	155
	TOTAL	911	258	879

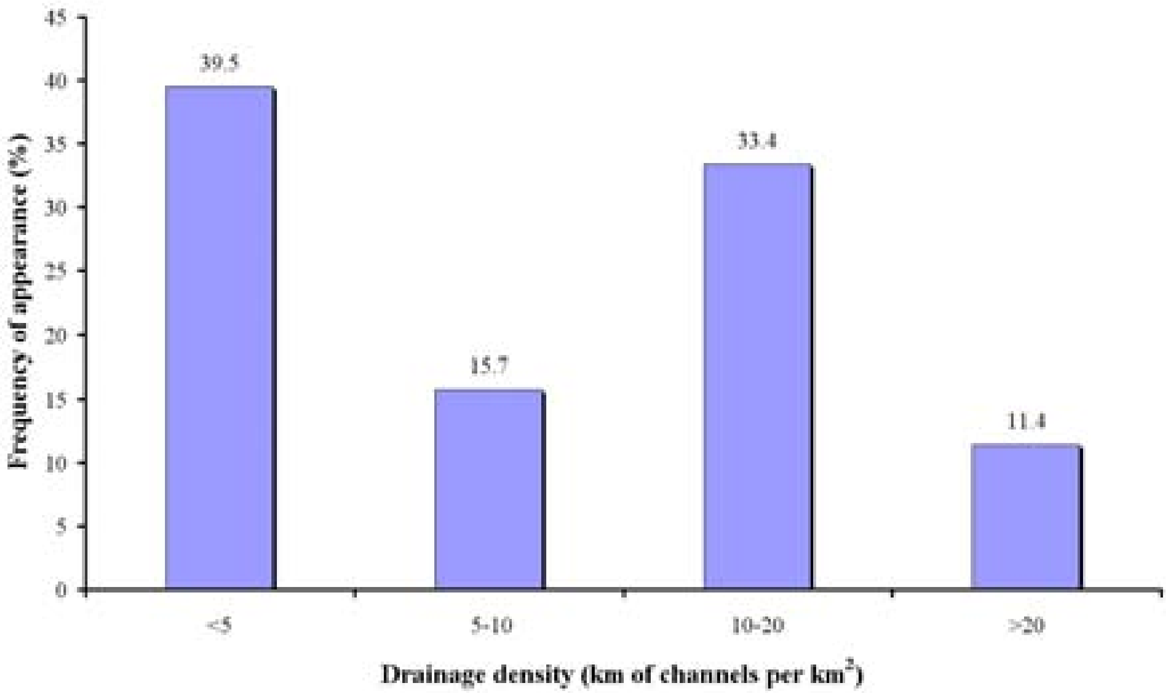

Fig. 41. Distribution of drainage density classes identified in the study field sites

Flooding frequency

Flood frequency is the probability of occurrence of damaging floods in a piece of land during the year. Floods are a function of climate variability (especially rainfall patterns), basin hydrology (including river bed shape), and the intensity of drainage and depth of flow, as well as soil characteristics, particularly water holding capacity of soils. Flooding can be the impact of extensive deforestation, widespread forest fires, overgrazing, collapse of terraces and soil conservation structures, accelerating surface water runoff and flooding intensity on the lowlands. A damaging flood is one that destroys or cause severe damage to the crops, land or infrastructures (Fig. 42a).

Flooding frequency data have been collected from the local administrations, local farmers or by personal estimation. The following classes of flooding frequency have been used for the purpose of this project: (a) never flooding, (b) very rare: once every 10 years, (c) rare: once every 6-10 years, (d) infrequent: once every 3-5 years, and (e) frequent: every 1-2 years.

Fig. 42a. Areas with rare (left) and frequent (right) flooding causing damage to the growing crops and to the land

As Table 5 shows, data on flooding frequency were collected relatively in few study field sites (258 field sites), corresponding to 5 study sites. The number is limited since this indicator was mainly filled in field sites in which soil salinization was the main process of land degradation and desertification. Since most of the questionnaire filled was located in hilly areas, therefore, the dominant class of flooding frequency was very rare or never known, covering 45.0% of the study field sites, corresponding to all sites of Novij Saratov-Russia, and Djanybek-Russia, and in few cases in Boteti Area-Botswana, and Crete-Greece study sites (Fig. 42b). The next important class was frequent (flooding once every 1-2 years), covering 21.7% of the study field sites. Such fields were mainly found in the study sites of Crete-Greece. Very rare flooding frequency (once every 10 years) has been recorded in 15.1% of the study field sites, corresponding mainly to Crete study site. The frequent (once every 1-2 years) flooding frequency was found in 11.2% of the study field sites, corresponding mainly to Crete-Greece study site. Finally, rare frequency of flooding (once every 6-10 years) has been mainly recorded in the Nestos Basin Maggana-Greece study site, covering 6.6% of the total field sites.

Impervious surface area

Impervious surface area or soil sealing occurs when agricultural or other rural land is taken into built environment (litorization). Soil sealing is the result of the development of housing, industry, transport and other physical infrastructure, including utilities (e.g. waste disposal) and military installations (Fig. 43). The EU Thematic Strategy for Soil Protection identifies soil sealing as one of the eight recognized threats to Europe’s soil resources. One major driver of soil sealing in the Mediterranean region is population pressure. Over the last three decades the Mediterranean countries have experienced a tremendous growth in population increase. In 2000 the 22 Mediterranean countries housed 428 million people compared to 285 million in 1970. Population pressure in the Mediterranean is exacerbated also by the tourism development which is the most preferred destination for European tourists. The impacts of soil sealing expansion in conjunction with climatic changes has greatly contributes to loss of fertile agriculture soils, expansion of agriculture in marginal lands, frequent flooding in the lowland due to artificial infrastructure cover of soil surface reducing water infiltration, water pollution due to overuse of pesticides and fertilizers, soil salinity due to irrigation with saline water and decreasing ground water enrichment and sea water intrusion into the aquifers. All these processes greatly contribute to land degradation and desertification.

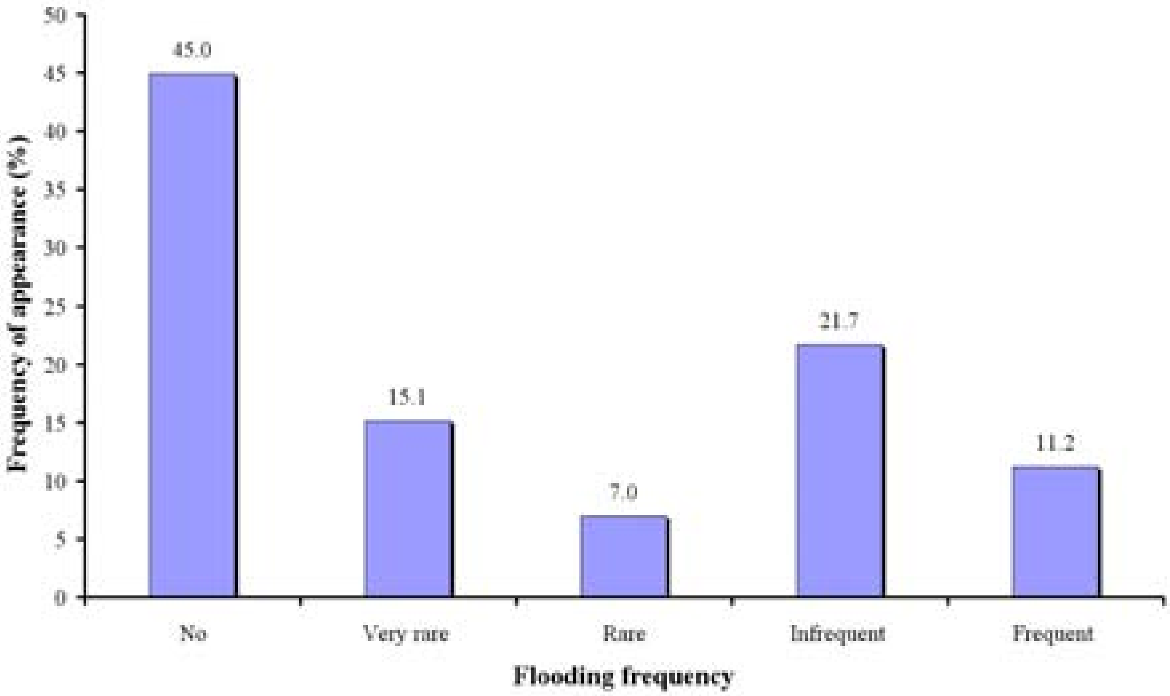

Fig. 42b. Distribution of flooding frequency recorded in the study field sites

The portion of impervious surface area has been estimated for the study sites by using aerial photographs of different periods. It has been defined as the surface area sealed in hectares per 10 km^2 of territorial surface per 10 years. The following classes have been distinguished: (a) low: <10 ha area sealed in a territorial of 10 km^2 per 10 years, (b) moderate: 10-25 ha per 10 km^2 of territorial surface per 10 years, (c) high: 25-50 ha per 10 km^2 of territorial surface per 10 years, and (d) very high: >50 ha per 10 km^2 of territorial surface per 10 years.

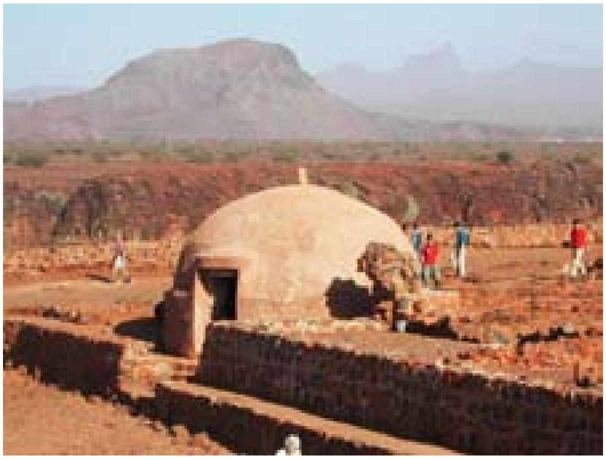

Fig. 43. Soil sealing due to cover of the soil surface with inert material causing severe problems of land degradation

Data for this indicator have been collected for 877 field sites, corresponding to 11 study sites (Table 5). As Fig. 44 shows, the dominant class of soil sealing is low (<10 ha 10 km^{-2} 10 $years^{-1}$), covering 43.4% of the study field sites. Such rate of soil sealing has been mainly identified in the study sites of Boteti Area-Botswana, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Novij Saratov-Russia, Djanybek-Russia, Secano Interior-Chile, Cointzio Catchment-Mexico, and Crete-Greece. The next important class of soil sealing is moderate (10-25 ha 10 km^{-2} 10 $years^{-1}$), covering 35.6% of the study field sites, corresponding mainly to the study sites of Boteti Area-Botswana, Konya Karapinar plain-Turkey, Santiago Island-Cape Verde, Eskisehir-Turkey, Guadalentin Basin Murcia-Spain, and Crete-Greece. Very high rate of soil sealing (>50 ha 10 km^{-2} 10 $years^{-1}$) has been defined in 17.1% of the study field sites, corresponding to the most touristic study site of Crete and in some cases in the Santiago Island-Cape Verde site. High rate of soil sealing has been identified in few cases (6.1% of the study field sites) (Fig. 44).

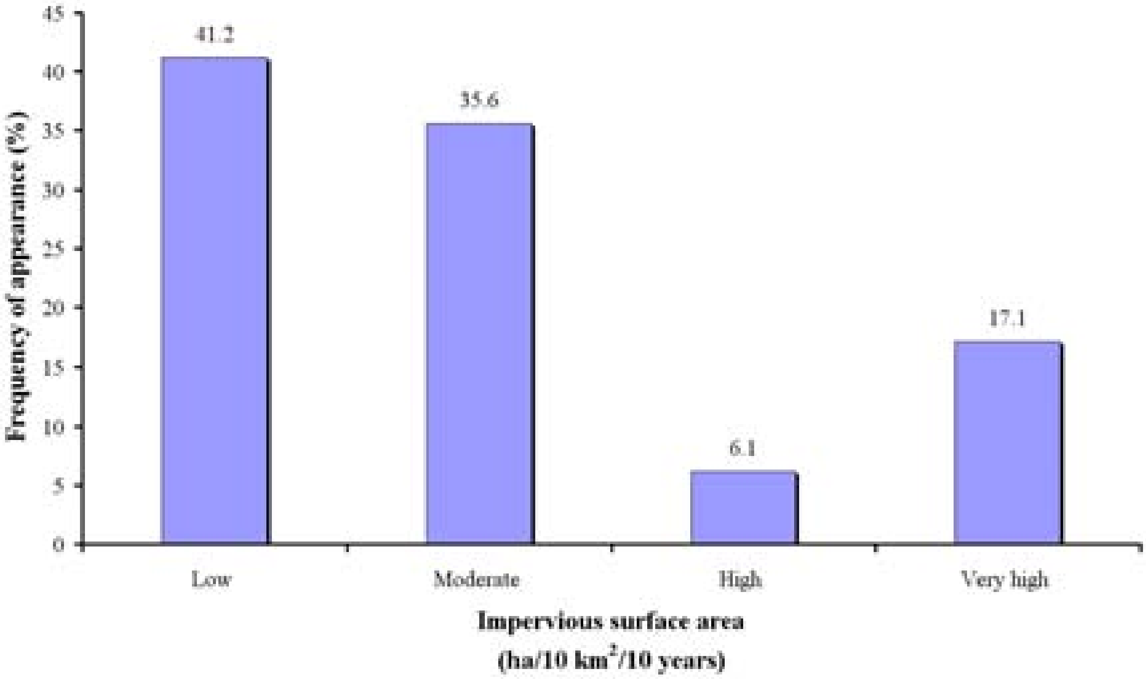

Fig. 44. Distribution of impervious surface area class defined in the various study sites

2.6 Forest fires indicators

One of the most important land degradation factors in Mediterranean climatic conditions is forest fires. In the last decades fires have become frequent in pine dominated forests and in scrublands. The majority of fires have been attributed to the people's carelessness. The majority of fires occur in areas with high xerothermic indices and moisture deficits. Soil dryness and wind speed are the principal factors of fire evolution. As it has been recognized by the UNCCD, dry sub-humid to semi-arid regions are especially prone to large wildfires. In contrast, drier areas do not support adequate vegetation, restricting fires propagation and spread. Human activities in densely populated areas are an important cause of fire ignition. In the last fifty years there has been a socio-economic transformation in Mediterranean Europe from rural to urban. As a consequence there has been a reduction of grazing animals, firewood exploitation, and land abandonment resulting in a dramatic increase in the availability of vegetation fuel. Furthermore, afforestation practices in many Mediterranean countries have been based on establishing coniferous and eucalyptus plantations without considering adequate forest management in the plantations once has been established. All these transformations have led to an increase of fire-prone ecosystems in the various landscapes.

Fire directly affects vegetation, soil, and the less mobile fauna. Burned ecosystems lack partially or totally vegetation covers for a period ranging from months to years. During this period, the soil is exposed to wind and water erosion followed by flooding of lowland and siltation of water reservoirs. Land plant cover is modified changing rainfall interception, rate of evapotranspiration and rainfall infiltration. Furthermore, forest fires greatly contribute to climate change by increasing greenhouse gasses. The following indicators have been considered in the DESIRE project related to forest fires: (a) fire frequency, (b) fire risk, and (c) burned area.

Fire frequency

It is defined as the frequency or return time in which a fire occurs. Fire frequency adversely affects regeneration of many plant and animal communities, with some of them experiencing loss of species diversity, followed by and site degradation. For example if a pine forest destroyed by fire twice in a period of 15 years, then this species can be recovering in the burned area naturally. Forest fires are frequent in pine forest. The frequency of fire occurrence is lower in grasslands, and mixed Mediterranean macchia with evergreen forests. Pastures are frequently subjected to man-induced fires in order to renew the biomass production. Human activities are causing major disturbances to natural fire regimes around the world: by increasing the rate of fires in areas where forests seldom would burn under natural conditions (Fig. 45), by suppressing natural fires, causing ecological damage and leading to infrequent, catastrophic fires due to a build-up of inflammable material.

This indicator requires information on both historic and current fire frequency. While current fire frequency data are not difficult to collect for large areas, it is not easy to determine the historic fire frequency on a restricted forest covered area. Fire frequency shows lately an increasing trend in forest located in the vicinity of urban areas. The limits of the indicator include the difficulty in finding statistical fire data and homogeneous data on burned surfaces for different European countries, at a municipality level. Data on historic fire regimes as well as recent data have been provided by EUROSTAT and National Statistics Services. Satellite data has been also used to measure current fire frequencies through systematic registration of ignition points. The following classes have been distinguished: (a) low, ecosystem burned every 50-100 years; (b) moderate, ecosystem burned every 25-50 years; (c) high, ecosystem burned every 15-25 years; (d) very high, ecosystem burned every <15 years.


Fig. 45. Extensive areas burned in Greece in 2007 causing severe problems of soil erosion, vegetation degradation and land desertification

As Table 6 shows, data for fire frequency have been given for 403 study field sites, corresponding to 8 study sites. One reason for collecting comparative to other indicators few data for this indicator is attributed to the many study field sites were located in agricultural areas. Fire frequency was low (once every 50-100 years) in the majority of the study field sites, covering 81.9% of the total sites. Such fields were found in the study sites of Boteti Area-Botswana, Novij Saratov-

Russia, Djanybek-Russia, Gois-Portugal, Eskisehir-Turkey, Cointzio Catchment-Mexico, and Konya Karapinar plain-Turkey (Fig. 46). Very high fire frequency has been identified in 11.7% of the study fields, corresponding mainly in the study sites of Mação- Portugal, and Boteti Area-Botswana. Moderate and high frequency (once every 25-50, 15-25 years, respectively) has been recorded in few field sites, corresponding mainly in the site of Boteti Area-Botswana (Fig. 46).

Table 6**. Number of field sites in which the indicators related to forest fires was recorded in the filled questionnaires**

site no	Study site	Number of field sites described for the indicator		
		Fire Frequency	Fire risk	Burned area
1	Rendina Basin, Basilicata, Italy	-	-	-
2	Loess Plateau, China	-	-	-
3	Nestos Basin, Maggana, Greece	-	-	-
4	Secano Interior, Chile	-	-	28
5	Novij, Saratov, Russia	62	-	22
6	Gois, Portugal	30	30	30
7	Mação, Portugal	31	31	31
8	Santiago Island, Cape Verde	-	-	103
9	Boteti Area, Botswana	47	30	37
10	Mamora/Sehoul, Morocco	-	-	120
11	Zeuss-Koutine, Tunisia	-	-	120
12	Guadalentin Basin, Murcia, Spain	-	-	121
13	Cointzio watershed, Mexico	20	20	87
14	Djanybek, Russia	69	40	40
15	Crete, Greece	-	-	155
16	Eskisehir, Turkey	70	70	70
17	Konya, Karapinar plain, Turkey	74	74	74
	TOTAL	403	295	1038

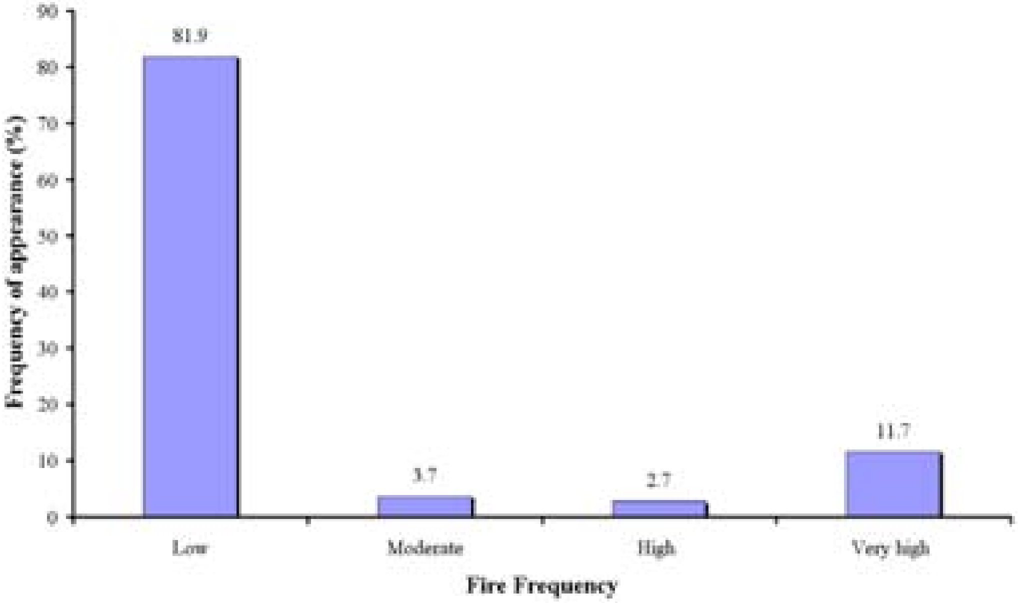

Fig. 46. Distribution of fire frequency recorded in the study field sites

Fire risk

Fire risk is determined by the particular composition of vegetation and therefore both by its flammability and combustion capacity and its capacity to recover after fire. Mediterranean vegetation type is highly flammable and combustible due to the existence of species with high content of resins or essence oils (Fig. 47). Fire risk has been estimated on the basis of the structure and the dominant vegetation species present in each study site. The following categories of fire risk have been defined: (a) low, including perennial crops, annual crops such as maize, tobacco, sunflower, etc.; (b) moderate, including annual crops such as cereals or meadows, deciduous oaks, mixed deciduous and evergreen oaks, mixed Mediterranean maquis and evergreen forests; (c) high, including Mediterranean maquis; and (d) very high, including coniferous forests.

The number of field sites in which the indicator fire risk was recorded was rather limited (295 field sites in 7 study sites) (Table 6). Based on the obtained data, the dominant class of fire risk as identified was low (Fig. 48), covering 72.9% of the total field sites and corresponding in the majority of the study sites in which this indicator was defined. The next important class of fire risk was very high covering 17.3% of the total field sites and corresponding mainly to the Mação- Portugal study site. Moderate and high fire risk has been recorded in 4.4% and 5.5% 0f the study field sites, respectively.

Fig. 47. Examples of areas with low fire risk (olive grove, left) and very high fire risk (pine forest, right)

Burned area

Every year, millions of hectares of the world's natural and agricultural areas are being consumed by fires, causing tremendous damage to the environment. The ecological and environmental impacts of fires are manifested by degradation of the quality of vegetation, accelerated soil erosion, loss of biodiversity, pollution of surface waters, and overall ecological retrogression. Furthermore, fires contribute to global climate change and warming. Biomass burning also results to the loss of an important sink for atmospheric carbon.

Burned area in this study has been defined as the average area burned per decade on a defined territorial surface. It is defined per decade using the annual data of natural and agricultural areas burned by wildfire, at municipality level at least. Such data have been provided by Eurostat and National Statistic Organizations. The following classes of burned area has been defined: (a) low, <10 ha of total burned area per decade on 10 km^2 of territorial surface; (b) moderate, 10-25 ha of total burned area per decade on 10 km^2 of territorial surface; (c) high, 26-50 ha of total burned area per decade on 10 km² of territorial surface; and (d) very high, >50 ha of total burned area per decade on 10 km² of territorial surface.

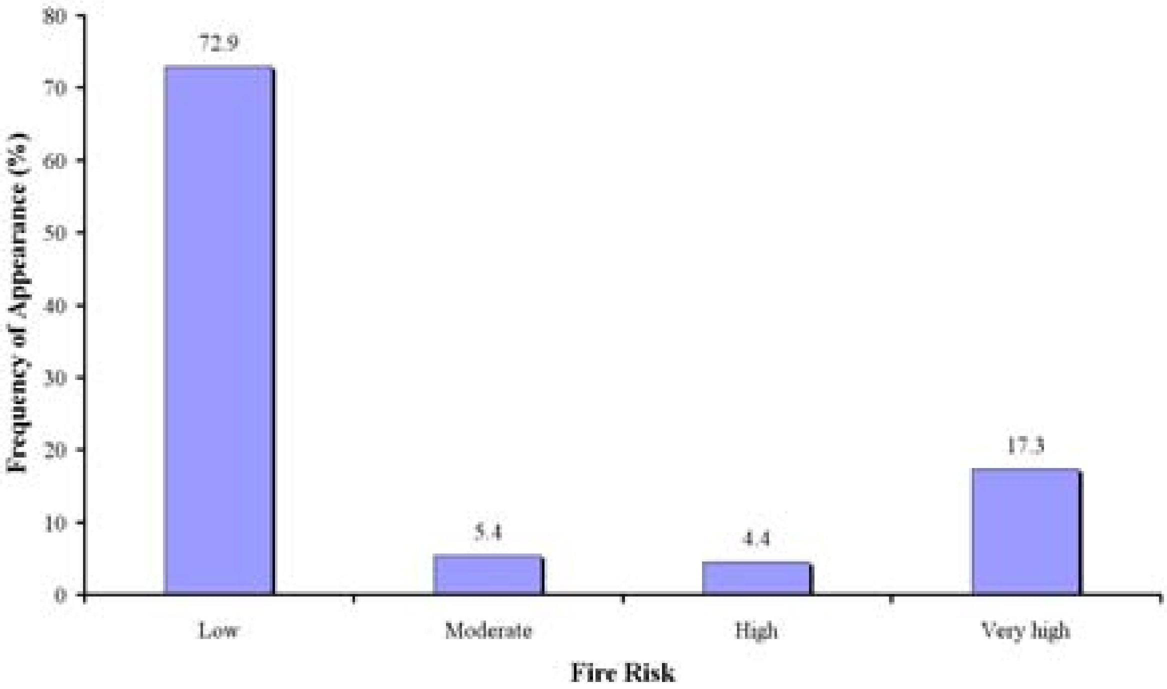

Fig. 48. Distribution of fire risk class of the various types of vegetation identified in the study field sites

As Table 9 shows, burned area has been defined for 138 field sites, corresponding to 14 study sites. The prevailing class of burned area rate (88.0% of total study field sites) was low (<10 ha decade^{-1} 10 km^{-2} of territorial surface), corresponding to Secano Interior-Chile, Boteti Area-Botswana, Konya Karapinar plain-Turkey, Santiago Island-Cape Verde, Eskisehir-Turkey, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, Djanybek-Russia, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico, Mamora Sehoul-Morocco, and Crete-Greece study sites. Moderate rate of burned area has been defined in 6.1% of the total study field sites, corresponding to Boteti Area-Botswana, and Crete-Greece study sites. Very high rate of burned area (>50 ha decade^{-1} 10 km^{-2} of territorial surface) has been recorded in 5.3% of the study field sites, corresponding to Mação-Portugal study site in which the highest fire frequency has been recorded (Fig. 49).

2.7 Indicators related to agriculture

Agriculture has greatly contributed to land degradation and desertification in the last decades due to its intensification (increase in fertilizers, using improved varieties, and irrigation) in certain areas, to expansion in hilly natural areas with poor soils, and abandonment when land productivity was low. Mismanagement of the land was stimulated in the previous century by socially and economy based political decisions that increased demographic dynamics leading to the movement of people and their agricultural activities to marginal areas, with poor soils not suitable for agriculture. The fast cultural, social, economic and technologic changes occurred in the decades of 60 and 70 of the last century led to a spectacular increase in crop yields, accompanied by increased rates of land degradation. The area cultivated in many areas of the world has been increased because the population increase and the development of new technologies that have made new areas suitable for farming. Dry farming was expanded in marginal lands while irrigated farming was conducted mainly in the most productive soils, in the lowlands. Human impact on the landscape was increasingly negative through conventional large scale extensive agriculture, generating a situation of degradation of soil properties affecting erosive processes. The main changes in soil characteristics due to the degradation were the decrease in organic matter content, increase in salinity, demotion of soil structure and soil compaction, decrease in water retention capacity and infiltration.

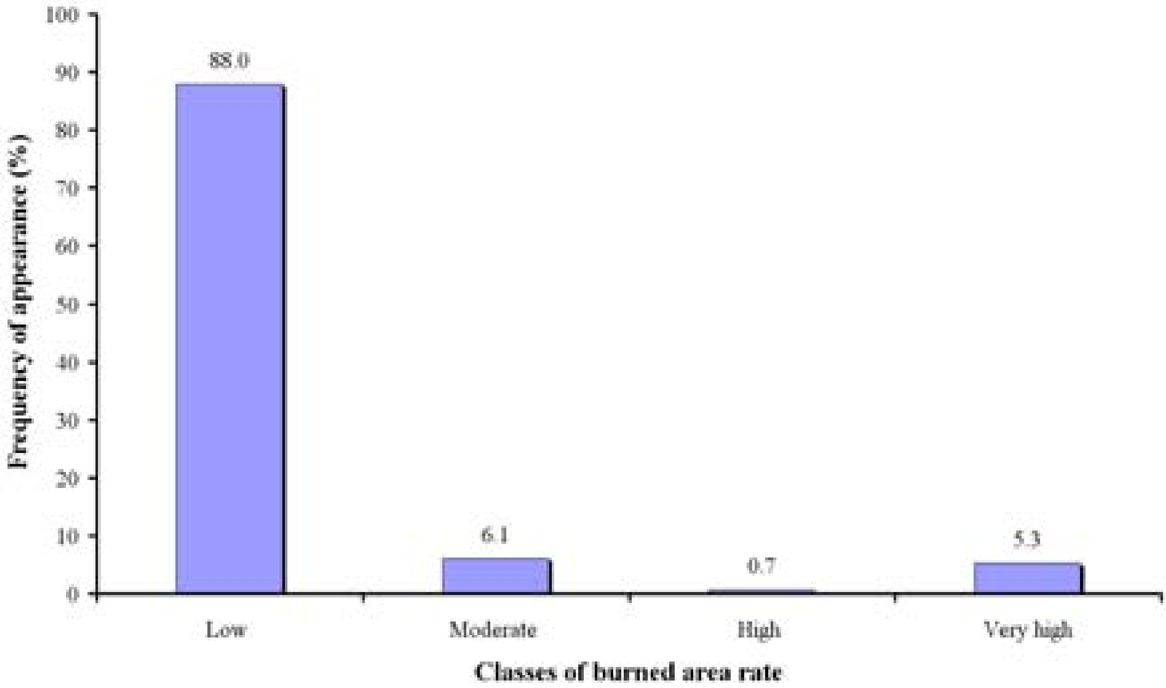

Fig. 49. Distribution of rate of burned area identified in the study field sites

The reasons leading to mismanagement of the land are closely related to social and economic changes in the rural areas. Low prices of dry farming products and competition from other countries resulted in low farmer’s income. Farmers then had to adopt different cultivation methods to get public subsidies or change to more profitable crops or to expand agriculture in marginal areas or to abandon the land and migrate in urban areas. These processes have favoured land fragmentation with parcels to be smaller and smaller. Furthermore, mismanagement of the land was related to social characteristics such as farmer age. Older farmers are more negative to change their practices be more aware of the degradation problems in contrast to young farmers who were more easily convinced to new technologies expecting increase of their income. Land abandoned has been a trend by new farmers in which inappropriate management practices were applied since their main purpose was to increase income. Low farmer’s income leads to low investment on applying measures for protection. Furthermore, growing economic activities like tourism have attracted labour due to the relatively high wages or having a parallel employment considering their farming activity as a secondary job taking less care of the land than before. The following indicators related to social and economic characteristics of agriculture have been considered in this project: (a) farm ownership, (b) farm size, (d) land fragmentation, (e) net farmer income, and (f) parallel employment.

Farm ownership

Farm ownership can affect land management practices. Usually farmers do not apply measures for land protection from degradation since they seek temporally only maximum profit. Farmers without a steady perspective in the property of the land are not encouraged to invest in soil conservation measures or make long-term investments. UNCCD has emphasized the importance of improvement of the institutional and regulatory framework of natural resource management to provide security of land tenure for local populations. Farm ownership represents a fundamental factor for decision-makers for addressing political measures to individual farmers or to more effective public level.

Farm ownership has been defined in this project as the percentage of rented agricultural land in the owner-farmed agricultural area. In each study field site the ownership status was identified by contacting the land user. Agricultural land is the sum of arable land, kitchen gardens (horticulture), permanent pastures and meadows and permanent crop. According to the EUROSTAT CODE the utilized agricultural area is classified as following: (a) owner–farmed, agricultural land being farmed by the holding which is the property of the holder or farmed by him as usufructuary or inheritable long-term lease holder or under some other equivalent type of tenure; (b) tenant–farmed, land rented by the holding in return for a fixed rent agreed in advance (in cash, kind or otherwise), and for which there is a (written or oral) tenancy agreement; (c) shared-farmed, land (which may constitute a complete holding) farmed in partnership by the landlord and the sharecropper under a written or oral share-farming contract, the output (either economic or physical) of the share cropped area is shared between two parties on an agreed basis; (d) state farm, and (e) other modes.

Based on the collected data, land ownership has been identified in 1291 field sites, corresponding to 15 study sites (Table 7). As Fig. 50 shows, 59.9% of the field sites described were owner-farmed corresponding mainly to the study sites of Secano Interior-Chile, Nestos Basin Maggana-Greece, Boteti Area-Botswana, Konya Karapinar plain-Turkey, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Eskisehir-Turkey, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Cointzio Catchment-Mexico, Gois-Portugal, Crete-Greece, and Mação- Portugal. The following important class of land ownership was shared-farmed, in which the farmed land is in partnership by the landlord and the sharecrop farmed under a written or oral share-farming contract. Such type of ownership has been identified in 14.6% of the study field sites, corresponding to all cases of the study site of Djanybek-Russia, and in some cases in the sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Novij Saratov-Russia, and Zeuss Koutine-Tunisia. State farm has been defined in 14.5% of the study field sites, corresponding to Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Konya Karapinar plain-Turkey, and Crete-Greece. Tenant-farmed has been identified in 6.0% of the study field sites, corresponding to Novij Saratov-Russia, and Santiago Island-Cape Verde sites.

Table 7**. Number of field sites in which the indicators related to agriculture was recorded in the filled questionnaires**

site no	Study site	Number of field sites described for the indicator				
		Farm ownership	Farm size	Land fragmentation	Net farm income	Parallel employment
1	Rendina Basin, Basilicata, Italy	-	-	-	-	-
2	Loess Plateau, China	-	-	-	-	-
3	Nestos Basin, Maggana, Greece	30	-	-	-	-
4	Gois, Portugal	30	-	-	30	
5	Mação, Portugal	31	-	-	31	-
6	Secano Interior,	28	28	28	28	28

	Chile					
7	**Boteti Area, Botswana**	**39**	**28**	**28**	**32**	**40**
8	**Novij, Saratov, Russia**	**60**	**22**	**22**	**22**	**84**
9	**Cointzio watershed, Mexico**	**87**	**37**	**37**	**47**	**37**
10	**Djanybek, Russia**	**109**	**40**	**40**	**40**	**69**
11	**Eskisehir, Turkey**	**70**	**70**	**70**	**70**	**70**
12	**Konya, Karapinar plain, Turkey**	**74**	**74**	**74**	**74**	**74**
13	**Santiago Island, Cape Verde**	**103**	**103**	**103**	**103**	**103**
14	**Mamora/Sehoul, Morocco**	**120**	**120**	**99**	**99**	**99**
15	**Zeuss-Koutine, Tunisia**	**120**	**120**	**120**	**120**	**120**
16	**Guadalentin Basin, Murcia, Spain**	**121**	**121**	**121**	**121**	**121**
17	**Crete, Greece**	**269**	**155**	**155**	**155**	**155**
	TOTAL	**1291**	**918**	**897**	**972**	**1000**

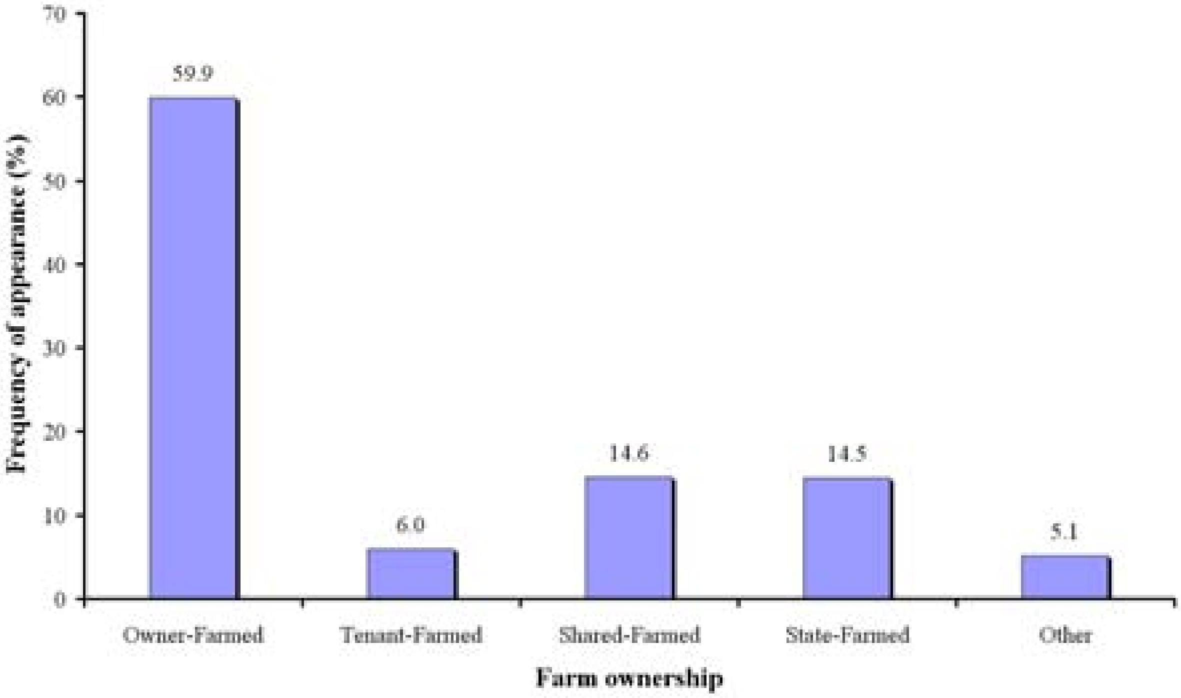

Fig. 50. Distribution of farm ownership categories identified in the study sites

Farm size

Farm size generally affects land management practices and organization of farm activities. Large farm size can have an impact on the shape of the farm such as uniform fields with less boundary features and isolated trees, as well as on the degree of intensification of operations as capital replaces labor which enables farmers to produce higher output from the land. The tendency toward greater concentration in production usually leads farmers to the replacement of mixed farming by more specific and uniform production such as livestock or arable based farms, etc. Studies conducted in the island of Lesvos (Greece) have shown that land use change has been affected by farm size. Land use change has occurred when farm size was greater than 10 hectares. In smaller farm sizes changes in land use were not so often.

Farm size is defined as the ratio between the number of farms belonging to the size classes less than 2 hectares and the number of farms belonging to the size classes more than 50 hectares. The farm size was identified after contacting the land user. This indicator contributes to the definition of the agricultural structure of the area affected by desertification. The following classes have been used in this project: less than 2 ha, 2-5 ha, 5-10 ha, 10-20 ha, 20-30 ha, 30-50 ha, 50-100 ha, and >100 ha.

As Table 7 shows, data on farm size has been collected in 972 study field sites, corresponding to 12 study sites. The dominant classes of farm size identified in the study field sites were less than 2 hectares and 10-30 hectres (Fig. 51), covering 22.2% and 22.3% of the total fields, respectively. Such farm sizes have been mainly found in the study sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Konya Karapinar plain-Turkey, Eskisehir-Turkey, and Crete-Greece. The next important classes of farm size were 2-5 and 30-50 ha, covering about the same percentage of the study field sites or 20.7% and 15.9%, respectively. Such farm sizes have been identified in the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, and Crete-Greece. Farm size classes 50-100 ha and >100 ha have been found in 1.7% and 13.1% of the study field sites, respectively, corresponding mainly in the study sites of Secano Interior-Chile, Boteti Area-Botswana, Mamora Sehoul-Morocco, and Djanybek-Russia. Farm sizes of 5-10 ha have been found in few cases (4.0% of the study field sites), corresponding to study sites of Secano Interior-Chile, Mamora Sehoul-Morocco, and Crete-Greece. In conclusion large field (>100 ha) sizes have been identified mainly in Djanybek-Russia and Secano Interior-Chile, and small farm sizes (<2 ha) mainly in Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, and Crete-Greece.

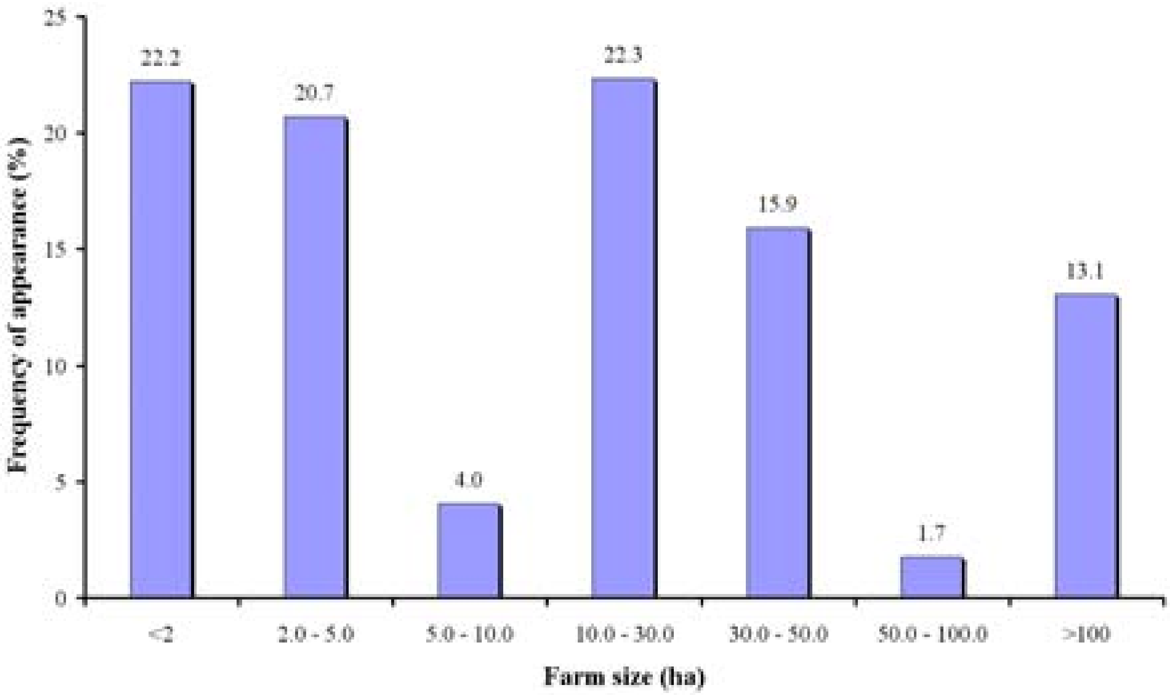

Fig. 51. Distribution of farm sizes classes defined in the study field sites

Land fragmentation

Land fragmentation can affect land management practices and decision-making related to the structure of the farm. A highly fragmented land is not easily to mechanized and cultivate in a direction in which soil erosion is restricted (Fig. 52). If the fields belonging to a farm are located in various locations then economic performance of various activities becomes less profitable and can generate the abandonment of the farm, worsening the quality of the environment. In extreme situation, marginal lands located at long distance from the farm centre can be progressively abandoned. Moreover, long distance located parcels can not easily controlled protection and maintenance of the landscape. Farm fragmentation in combination with adverse soil, topographic and climatic conditions affected land use change decision-making. Studies conducted in the island of Lesvos have shown that as the number of parcels in each farm increased, land use remained often unchanged. When a farm was divided in several parcels distributed in various locations, farmer used to allocate land uses according to the land productivity keeping such distribution usually unchanged for long periods.

Land fragmentation has been defined as the number of parcels per holdings. Data on land fragmentation related to the study field sites have been collected by contacting the land user. The following classes have been defined for this project: (a) 1-3 parcels, (b) 4-6 parcels, (c) 7-9 parcels, (d) 10-12 parcels, (e) 13-15 parcels, (f) 16-19 parcels, and (g) >19 parcels.

Fig. 52. Land characterized as highly fragmented (left) and low fragmented (right) in which fields are uniform concerning crop and cultivation

Based on the obtained data (Table 7), land fragmentation has been defined on 918 field sites, corresponding to 12 study sites. As Fig 53 shows, the dominant class of land fragmentation in the study field sites was 1-3 parcels per holding, covering 36.8% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Boteti Area-Botswana, and Konya Karapinar plain-Turkey, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, and Zeuss Koutine-Tunisia. The following important class of land fragmentation was 7-9 parcels, covering 30.2% of the total fields. Such conditions of land fragmentation have been mainly defined in the study sites of, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Eskisehir-Turkey, and Crete Greece. Parcels 13-15 per holding have been found in 14.7% of the study field sites, corresponding to Secano Interior-Chile, Mamora Sehoul-Morocco, and Guadalentin Basin Murcia-Spain study sites. The next important class of land fragmentation was 4-6 parcels per holding, covering 12.9% of the study sites, and corresponding to Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Novij Saratov-Russia study sites. Finally, very high land fragmentation (>19 parcels per holding) was found in 4.5% of the study field sites, corresponding only to Djanybek-Russia study site (Fig. 53).

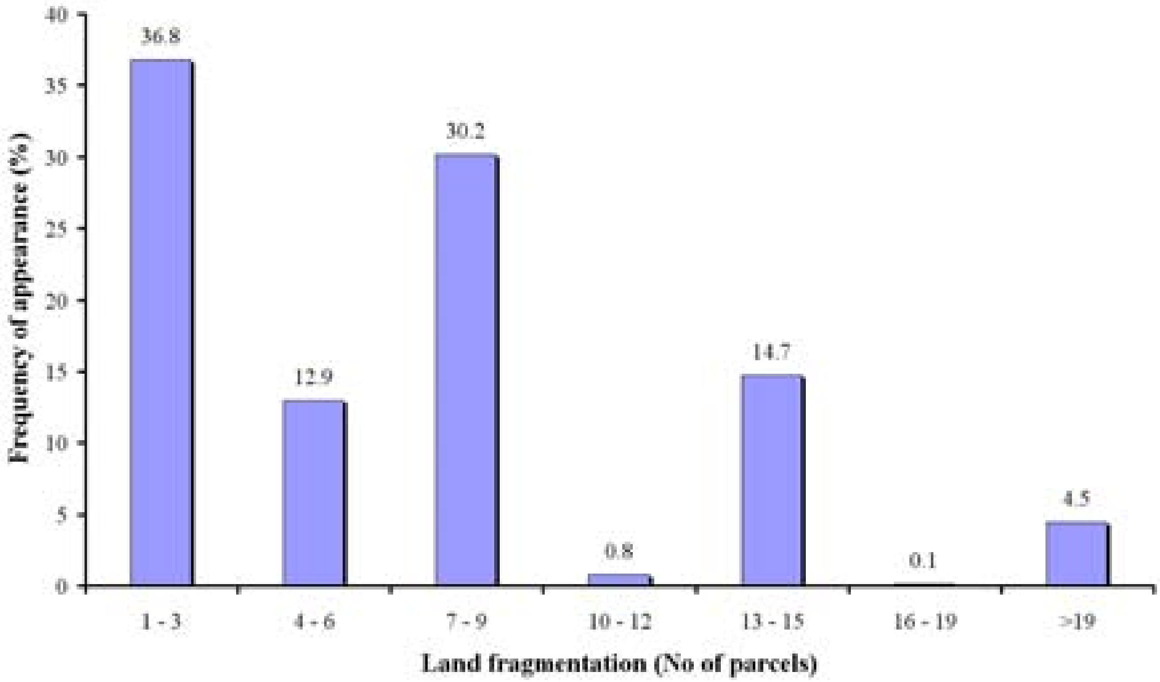

Fig. 53. Distribution of land fragmentation classes defined in the study field sites

Net farm income

The farm income plays a very important role in defining the strategies of the farmers with respect to the land management. If the farmers get sufficient income from the farm, they will adopt all possible strategies to preserve the soils and the environment. Farmers in Mediterranean Europe face severe problems due to international competition with the price of their products to be low compared to previous decades. As a result of the low income, land investment including soil erosion or soil salinization protection measures is limited. Many of the traditional cultivation practices such as terraced areas around the Mediterranean have been abandoned especially those cultivated with cereals and in some cases with olives and vines due to declined of farm income. Abandonment of such areas results in terraces collapse with soil to be washed out immediately by surface water runoff, leading to land desertification.

The Net Farm Income has been defined as: NFI = Total Output (A) - All Inputs (B) + net public receipts (subsidies less farm taxes). Data on farm income for this project have been collected in collaboration with the land user the following classes have been defined: (a) low, range: <Local Mean-St. Dev.; (b) moderate, range: > Local Mean - St. Dev. < Local Mean, (c) high, range: > Local Mean < Local Mean + St. Dev.; and (d) very high, range: > Local Mean + St. Dev.

As Table 7 shows, data on net farm income have been collected in 1000 study fields, corresponding to 14 study sites. The dominant class of net farm income was moderate, covering 64.3% of the study field sites (Fig. 54). Such net farm income has been found in the study sites of Secano Interior-Chile, Boteti Area-Botswana, Gois-Portugal, and Konya Karapinar plain-Turkey, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Novij Saratov-Russia, Djanybek-Russia, Cointzio Catchment-Mexico, and Crete-Greece. The following important class of net farm income was low, covering 29.7% of the study field sites, and corresponding to the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico, Gois-Portugal, and Mação- Portugal. High and very high farm income has been identified in few cases (4.6%, and 1.3% of the study fields sites), corresponding to few cases of the study sites Boteti Area-

Botswana, Mamora Sehoul-Morocco, Gois-Portugal, Novij Saratov-Russia, and Djanybek-Russia. In conclusion the majority of the farmers in which the study fields belongs have moderate to low farm income and measures for environmental protection against land desertification is expected to be limited.

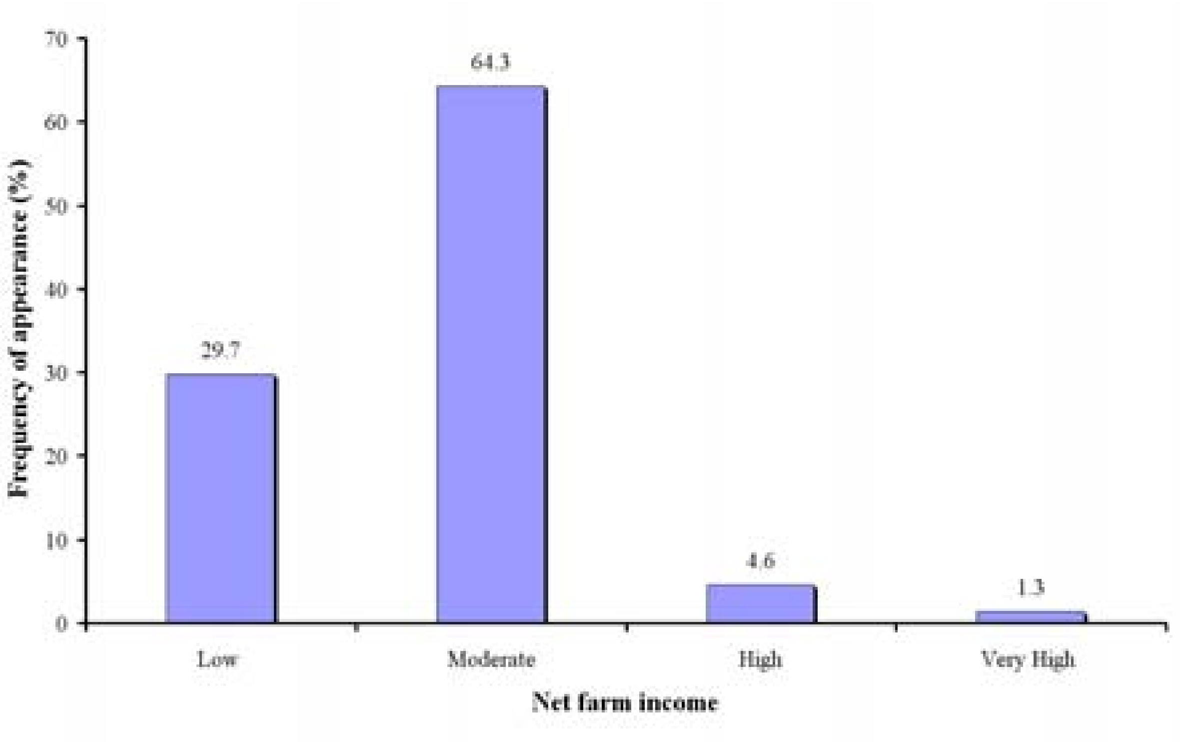

Fig. 54. Distribution of net farm income classes defined in the study field sites

Parallel employment

As it was shown in the previous indicator, farmers income in the study sites is low to moderate pushing them in parallel employment in other economic sectors such as tourism, industry, etc. Under such economic conditions, farming becomes a second activity with limited actions for protection of the environment from desertification. In some cases low productivity lands are abandoned with positive or negative consequences depending on the soil and climatic conditions of the area (Fig. 55).

Parallel employment in this project has been identified by contacting the land user. It has been defined as the percentage of off-farm income as a percentage of the total family income (Family Farm Income plus Off-Farm Income) or simply as parallel employment in other sectors except agricultural such as industry, municipality, state, etc.

Fig. 55. Examples of negative (left) and positive effects of land abandoned due to parallel employment in other economic sectors outside of agriculture

Data for this indicator have been collected in 897 field sites, corresponding to 13 study sites (Table 7). As Fig. 56 shows, the majority of the farmers (52.0% of the total field's sites) do not work parallel in other economic sectors except agriculture. Such conditions of exclusively work in agriculture were found in all field sites of Secano Interior-Chile, Konya Karapinar plain-Turkey, Novij Saratov-Russia, Djanybek-Russia, and Crete-Greece, and in some field sites of Boteti Area-Botswana, Santiago Island-Cape Verde, and Mamora Sehoul-Morocco study sites. The most important parallel employment was found in industry for 19.0% of the study field sites, corresponding mainly to the study sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, and Guadalentin Basin Murcia-Spain. Parallel employment in state, municipality, and other economic sectors were found in some cases, covering 7.4%, 5.4%, and 16.2% of the study fields, respectively. Such field sites where identified in Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Eskisehir-Turkey, Cointzio Catchment-Mexico, and Zeuss Koutine-Tunisia study sites.

2.8 Indicators related to cultivation

In the last decades soil management has changed dramatically by introducing new land cultivation implements and especially the tractor. The availability of heavy powerful machinery favored deep soil plowing and high speeds in directions usually perpendicular to the contour lines. This resulted in the displacement of huge amounts of soil materials from the upper convex parts (summit, shoulder, back slope) of a hill slope to the concave parts (footslope, toeslope) and decreased significantly the production of the various crops. Such cultivation practices have greatly contributed to deterioration of soil quality for plant growth due to tillage erosion. Tillage erosion affects soil quality for long terms, by changing soil depth and consequently water holding capacity, nutrient availability, organic matter content, and crop yield. The effects of soil erosion on productivity depend largely on the thickness and quality of the topsoil and on the nature of the subsoil. Productivity of deep soils with thick topsoil and excellent subsoil properties may be virtually unaffected by erosion. However, most hilly soils are shallow or have some undesirable properties in the subsoil such as petrocalcic horizon, or bedrock that adversely affects yields. In either case, productivity will decrease as the topsoil gets thinner and undesirable subsoil is mixed into the Ap-horizon by tillage, or as water-storage capacity and effective rooting depth are decreased. Important indicators considered in this project for assessing land degradation and desertification risk are the following: (a) tillage operations, (b) tillage depth, (c) tillage direction, and (d) mechanization index (Table 8).

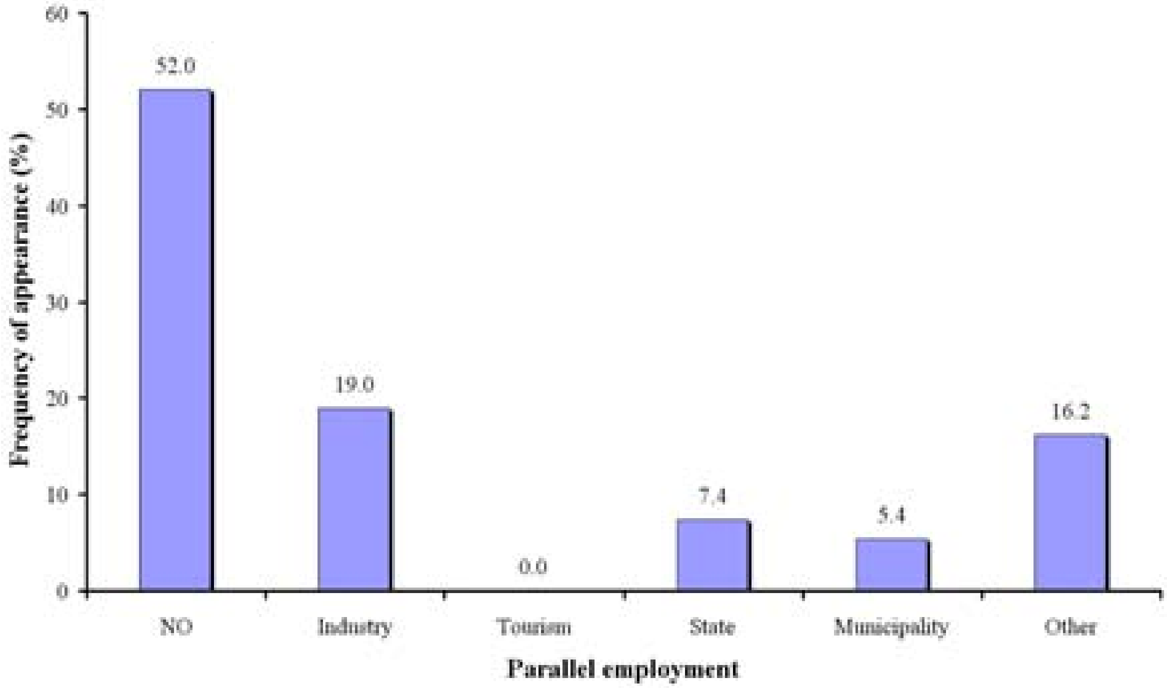

Fig. 56. Distribution of parallel employment of farmers in other sectors except agriculture defined in the study field sites

Table 8. **Number of field sites in which indicators related to cultivation was recorded in the filled questionnaires**

site no	Study site	Number of field sites described for the indicator				
		Tillage operations	Tillage depth	Tillage direction	Frequency of tillage	Mechanization index
1	Nestos Basin, Maggana, Greece	-	-	-	-	-
2	Mação, Portugal	-	-	-	-	-
3	Gois, Portugal	-	-	-	-	-
4	Djanybek, Russia	29	-	-	-	-
5	Boteti Area, Botswana	22	10	10	0	8
6	Secano Interior, Chile	28	28	28	28	-
7	Rendina Basin, Basilicata, Italy	30	30	30	-	30
8	Novij, Saratov, Russia	84	22	22	0	-
9	Cointzio watershed, Mexico	37	37	37	36	-
10	Eskisehir, Turkey	70	70	70	0	-
11	Konya, Karapinar plain, Turkey	74	74	74	-	74
12	Santiago Island, Cape Verde	103	103	103	77	-
13	Zeuss-Koutine, Tunisia	120	120	120	69	-
14	Crete, Greece	155	155	155	0	-
15	Mamora/Sehoul, Morocco	120	120	120	120	-

16	**Guadalentin Basin, Murcia, Spain**	**121**	**121**	**121**	**121**	**-**
17	**Loess Plateau, China**	**150**	**150**	**150**	**-**	**150**
	TOTAL	**1143**	**1040**	**1040**	**451**	**262**

<u>Tillage operations</u>

Tillage operations include the cultivation practices conducted by the various tillage implements such as mouldboard, chisel, duck foot chisel, harrow, etc. The various tillage implements cause various erosion rates. For example a tandem disk may be more erosive than a mouldboard plough operation because it translocates more soil with greater variability throughout the landscape. The chisel plough may be equally erosive as the mouldboard plough. Large aggressive tillage implements, operating at excessive depths and speeds are more erosive than conventional ones. Tillage operations have been defined after contacting the land owner. The following tillage operations have been distinguished: no tillage, ploughing, disking, harrowing, and cultivator operation (Fig. 57)

Fig. 57. Tillage implement used for cultivation of hilly areas (left) preparing the soil for planting (right)

As Table 8 shows, data for this indicator have been collected in 1143 field sites, corresponding to 14 study sites. Based on the obtained data, the most important tillage operations were no tillage operations or minimum recorded in 42.2% of the study field sites, corresponding in the study sites of Secano Interior-Chile, Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Loess Plateau-China, and Crete-Greece. No tillage operations have been defined in areas cultivated with perennial crops such as olives and in areas used as pastures. The next important class was ploughing, covering 33.5% of the study field sites (Fig. 58). Such tillage operation has been defined in all study field sites of Karapinar plain-Turkey, Eskisehir-Turkey, Cointzio Catchment-Mexico, Novij Saratov-Russia, and Djanybek-Russia, and in some cases in the study sites of Secano Interior-Chile, Boteti Area-Botswana, Rendina Basin Basilicata-Italy, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Loess Plateau-China, and Crete-Greece. Ploughing of the soil has been mainly conducted in areas cultivated with annual crops such as cereals, cotton, vegetables, etc. Disking and harrowing operations have been identified in 16.1% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico, Guadalentin Basin Murcia-Spain, Loess Plateau-China, and Crete-Greece. Such tillage operations have been applied mainly in perennial crops such as olives, vines, oranges, etc. Tillage operation by cultivator has been defined in very few cases (2.4%) of the study field sites (Fig. 58), corresponding mainly in the study sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, and Crete-Greece. Finally other types of cultivation of the land have been defined in 5.8% of the study fields. This is a special type of cultivation applied mainly in hilly areas with very steep slopes of Santiago Island-Cape Verde in which the land is cultivated by hand in rows located parallel to the contour lines in order to conserve water and reduce soil erosion by surface water runoff (Fig.59).

Fig. 59. Cultivation of the land in rows parallel to the contour lines (left) and experimental station assessing the effectiveness of these cultivation practices in conserving water and reducing soil erosion in Santiago Island-Cape Verde

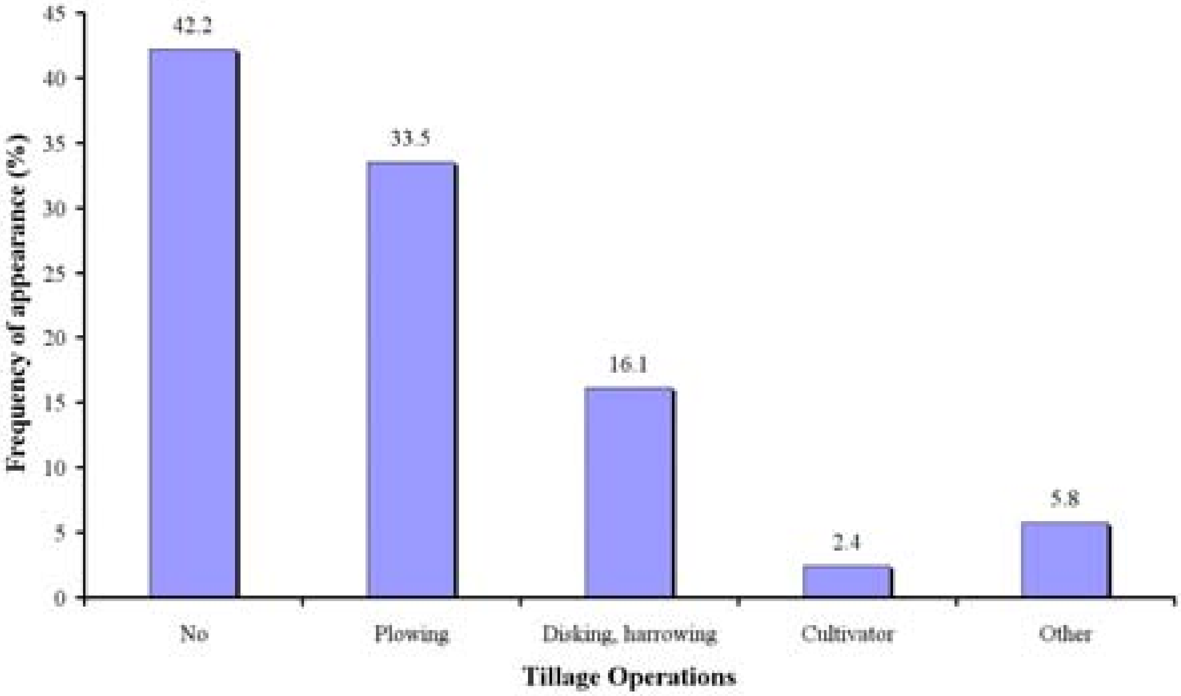

Fig. 58. Distribution of various tillage operations conducted in the study field sites

__Frequency of tillage__

As it was mentioned above tillage erosion tillage erosion is considered as the main cause of soil translocation from the upper hilly areas down slope to the lower land. Studies conducted during the execution of the EU research project TERON have shown that several factors affect the annual soil loss due tillage erosion such as type of tillage instrument, plow depth, wheel speed of the tractor, soil moisture content, slope gradient, direction of tillage operation, frequency of tillage operations, etc. One of the practices for reducing tillage erosion is minimum frequency of tillage operations. The frequency of tillage has been defined in this project as the number of tillage operations per year conducted by the farmer. It has been determined by contacting the land owner. The following classes of tillage frequency have been used: no tillage, tillage once per year, tillage twice per year, tillage three times per year, and tillage four times per year.

Data for tillage frequency have been collected in 451 study field sites, corresponding to 10 study sites. The analysis of the data showed that soils are tilled twice a year in 35.5% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico, and Crete-Greece (Fig 60). Three and four times tillage operations per year have been recorded in about equal number of field sites, covering 9.8% and 8.2% of the cases, respectively. Such cultivation practices have been found in the study sites of Secano Interior-Chile, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Cointzio Catchment-Mexico, and Zeuss Koutine-Tunisia. Tillage frequency once per year has been defined in 15.7% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Crete-Greece. Finally, no tillage operations have been recorded in 33.7% of the study field sites, corresponding to the study sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Crete-Greece.

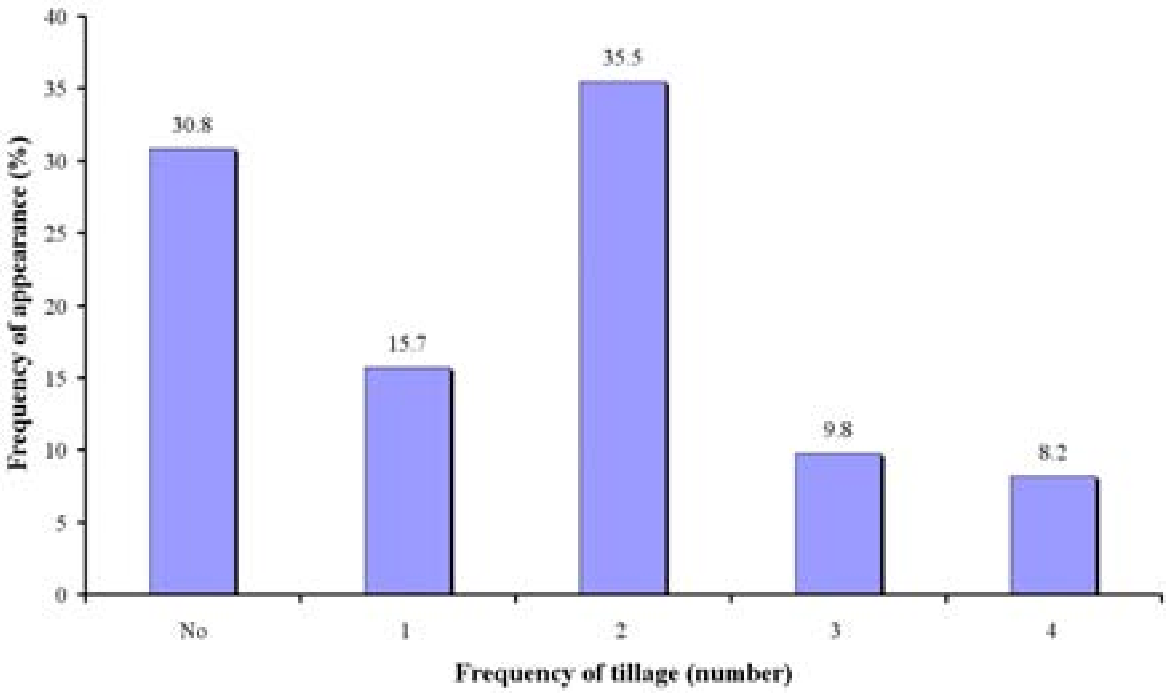

Fig. 60. Distribution of tillage frequency recorded in the study field sites

<u>Tillage depth</u>

Tillage depth corresponds to the depth that tillage implements such as mouldboard plough, cultivator, chisel plough, harrow etc. are disturbing the soil. The deeper the soil is ploughed the greater the soil displacement in the direction of tillage. Studies on tillage erosion conducted during the execution of the EU research project have been shown that soil displacement was reduced to about one third when plow depth was decreased from 40 cm to 20 cm. The effect of plow depth on soil displacement is especially pronounced on steep slopes where the furrow slice with shallow plowing sometimes do not completely turn but it remains in an angle usually perpendicular to the soil surface, so that soil displacement is greatly reduced (Fig. 61). When furrow slice is reversed in the down or up slope direction (independently of tractor travel direction), soil displacement is greater because gravity acts as an additional force displacing farther the soil. Of course other parameters besides plowing depth and slope gradient could affect reversion and breaking down of furrow such as tractor speed, soil moisture content, soil consistence, rock fragment content, etc.

Tillage depth has been defined by conducting the land user or the extension services of the related institutes. Also plough depth was easily to measure in the field by digging the upper soil layer and measuring the depth in which tillage implements reach. The following classes have been defined: (a) shallow, tillage depth <20 cm; (b) moderate deep, tillage depth 20-30 cm; (c) deep, tillage depth 30-40 cm; and (d) very deep, tillage depth >40 cm.

Fig. 61. Displacement of soil to the direction of ploughing accompany with reversion of plough slice due to the deep ploughing (left) and displacing huge amounts of soils from the upper convex and linear part of the slope and depositing in the lower concave part (right)

As Table 8 shows, data on tillage depth have been collected in 1040 study field sites, corresponding to 13 study sites. As Fig. 61 shows, the dominant class of tillage depth is 20-30 cm covering 26.7% of the study field sites. Such tillage operation has been mainly found in the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Boteti Area-Botswana, and Konya Karapinar plain-Turkey, Sehoul-Morocco, Eskisehir-Turkey, Cointzio Catchment-Mexico, Guadalentin Basin Murcia-Spain, and Crete-Greece. The next important class of tillage depth was less than 20 cm, covering 20.4% of the total fields, and corresponding mainly to the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece. Deep (30-40 cm) and very deep (>40 cm) plowing has been defined in few cases, covering 5.1% and 2.3% of the study field sites. Such cases of deep plowing have been described in the study sites of Rendina Basin Basilicata-Italy, Novij Saratov-Russia, and Loess Plateau-China. Finally, the dominant class was no tillage operations, covering 45.5% (Fig. 61) of the total fields, with all the positive effects on soil quality and soil erosion protection. Such type of land management has been found in the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Loess Plateau-China, Eskisehir-Turkey, Konya Karapinar plain-Turkey, Boteti Area-Botswana, and Crete-Greece. In conclusion, tillage operations are mainly conducted in relatively shallow depths or no tillage operations are applied, reducing significantly tillage erosion and land degradation in the study field sites.

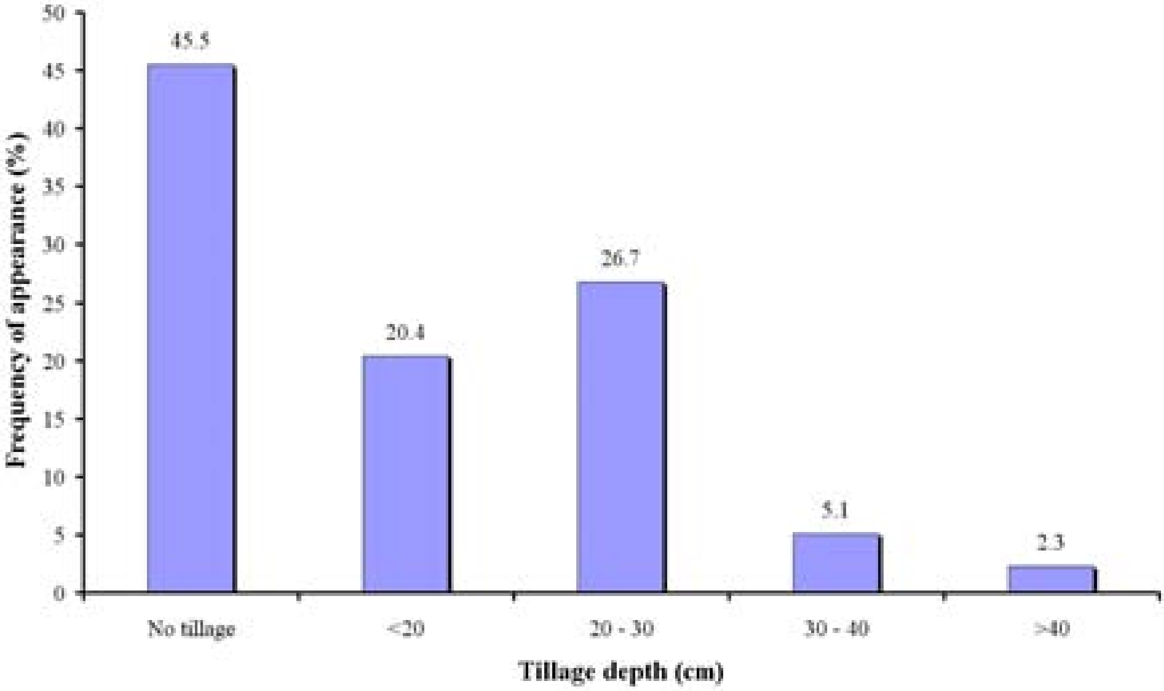

Fig. 61. Distribution of tillage depth classes defined in the study field sites

Tillage direction

The soil can be tilled in various directions parallel or perpendicular to the contour lines or in oblique lines depending on the slope gradient, the farm size and farm shape. The various cultivation practices such as tillage direction, direction of furrow reversion, and plough depth have variable effect on soil displacement. By ploughing the soil at shallow depth in any direction of tillage operation, tillage erosion is significantly reduced. When the physiographic conditions allowed the movement of tractor along the contour lines, then soil displacement is highly restricted. Any other direction of tillage operation increases tillage erosion. If the plough layer is moved to the up slope position under any tillage operation, then soil displacement could be considered as an operation for restoring and conserving degraded hilly areas. In hilly areas with steep slopes, where contour farming is impossible, then the soil can be ploughed perpendicular or in oblique lines but ploughing the soil at shallow depth and moving preferably the plough layer to the up slope direction.

The following categories of tillage direction have been distinguished in this project: (a) downslope (Fig. 62), (b) upslope, (c) parallel to contour upslope furrow, (d) parallel to contour downslope furrow, (e) downslope oblique (Fig. 62), and (f) upslope oblique. Tillage direction has been defined by conducting the land owner or by identified in the field by observing the furrow lines.

Fig. 62. Ploughing the soil perpendicular to the contour lines (left) and in oblique line (right)

Data for this indicator have been collected in 1040 field sites, corresponding to 12 study sites (Table 8). As Table 9 shows, the dominant direction of ploughing in the study field sites was downslope, covering 19.2% of the total fields. This type of tillage direction causes the highest rates of soil displacement in hilly areas. Such type of tillage operation has been defined in the study sites of Secano Interior-Chile, Konya Karapinar plain-Turkey, Mamora Sehoul-Morocco, Eskisehir-Turkey, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, and Crete-Greece. The next important tillage direction defined was parallel to the contour line with up-slope reversion of furrow, covering 11.1% of the study fields, and corresponding to some cases in the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Crete-Greece, and Loess Plateau-China. The next important tillage direction was parallel to contour lines with down-slope reversion of furrow, covering 6.5% of the study fields, corresponding to the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Boteti Area-Botswana, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Guadalentin Basin Murcia-Spain. Downslope ploughing in oblique direction has been found in 8.2% of the study field sites, corresponding to the study sites of Rendina Basin Basilicata-Italy, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, Cointzio Catchment-Mexico, and Crete-Greece. Upslope or upslope oblique tillage direction has been defined in few cases (0.3%, and 3.2% of the study sites), corresponding to the study sites of Secano Interior-Chile, Rendina Basin Basilicata-Italy, Novij Saratov-Russia, and Loess Plateau-China. Finally, no tillage has been defined in half of the study field sites (51.5%) (Table 8b), corresponding to the study sites of Rendina Basin Basilicata-Italy, Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Loess Plateau-China, and Crete-Greece.

Table 8b. Distribution of tillage directions defined in the study field sites

a/a	Tillage direction	Frequency of appearance (%)
1	Downslope	19.2
2	Upslope	0.3
3	parallel to contour, up-slope furrow	11.1
4	parallel to contour, down-slope furrow	6.5
5	downslope oblique	8.2
6	upslope oblique	3.2
7	no tillage	51.5

Mechanization index

It is defined as the motor vehicles, machinery used by the agricultural holding expressed in terms of horsepower (HP) per hectare of the Utilized Agricultural Area. The indicator gives a measure of how agricultural activities contribute to physical soil degradation. According to the Eurostat Glossary the following categories of machineries are distinguished: (a) Four-wheeled tractors, track-laying tractors, tool carriers, (b) Cultivators, hoeing machines, rotary hoes, motor mowers, (c) combine harvesters, and (d) other fully mechanized harvesters (Fig. 63). Utilised Agricultural Area (UAA) is the sum of Arable Land, kitchen gardens, permanent pasture and meadow, permanent crops (Eurostat). For calculation of mechanization index the ratio of the total horsepower (HP) of each tractor, cultivator, and piece of machinery has been divided by the hectares of UAA.

Fig. 63. Machinery used for calculation of mechanization index of a farm

Data for mechanization index of the study field sites have been collected for limited number of study sites (4 study sites), corresponding to 262 field sites (Table 8). As Fig. 64 shows, the prevailing class of mechanization index of the study field sites was low, covering 56.5% of the total fields, corresponding to the study sites of Loess Plateau-China, and Boteti Area-Botswana. The next important class of mechanization index was low, covering 32.4% of the study field sites. Such mechanization index has been defined in the study sites of Konya Karapinar plain-Turkey, and Boteti Area-Botswana. Finally, high mechanization index has been defined in 11.1% of the study field sites, corresponding to some study sites of Rendina Basin Basilicata-Italy, and Loess Plateau-China.

2.9 Indicators related to animal husbandry

Desertification of grazing lands and landscapes caused by grazing animals is a complex process affecting both vegetation and soil characteristics. Grazing animals remove in the first stage the more palatable species followed by less palatable ones, which finally these species dominate in the grazed area. In addition, trampling on the soil surface by the animal hooves exerts high pressure resulting in soil compaction, digging and soil structure deterioration. Therefore, degradation of vegetation, accompanied by decrease in plant cover and destruction of surface soil aggregates, favors surface water runoff generation and soil loss. Soils in grazing lands are shallow overlying the bedrock. Thus any loss of soil negatively affects vegetation growth and water storage capacity, leading in extreme cases to desertification. Besides overgrazing, undergrazing can also cause desertification due to the growth of high amount of flammable biomass affecting ignition of wildfires and leading to high erosion rates and degradation of the land. In addition, undergazed lands which are not burned are invaded by woody species resulting in loss of biodiversity due to high plant competition which is also a form of ecological decline. Therefore, a sustainable grazing of the pasture land is considered the best land management practice for protecting such areas from desertification. The following two indicators have been selected for assessing desertification risk related to grazing: (a) grazing control, and (b) grazing intensity.

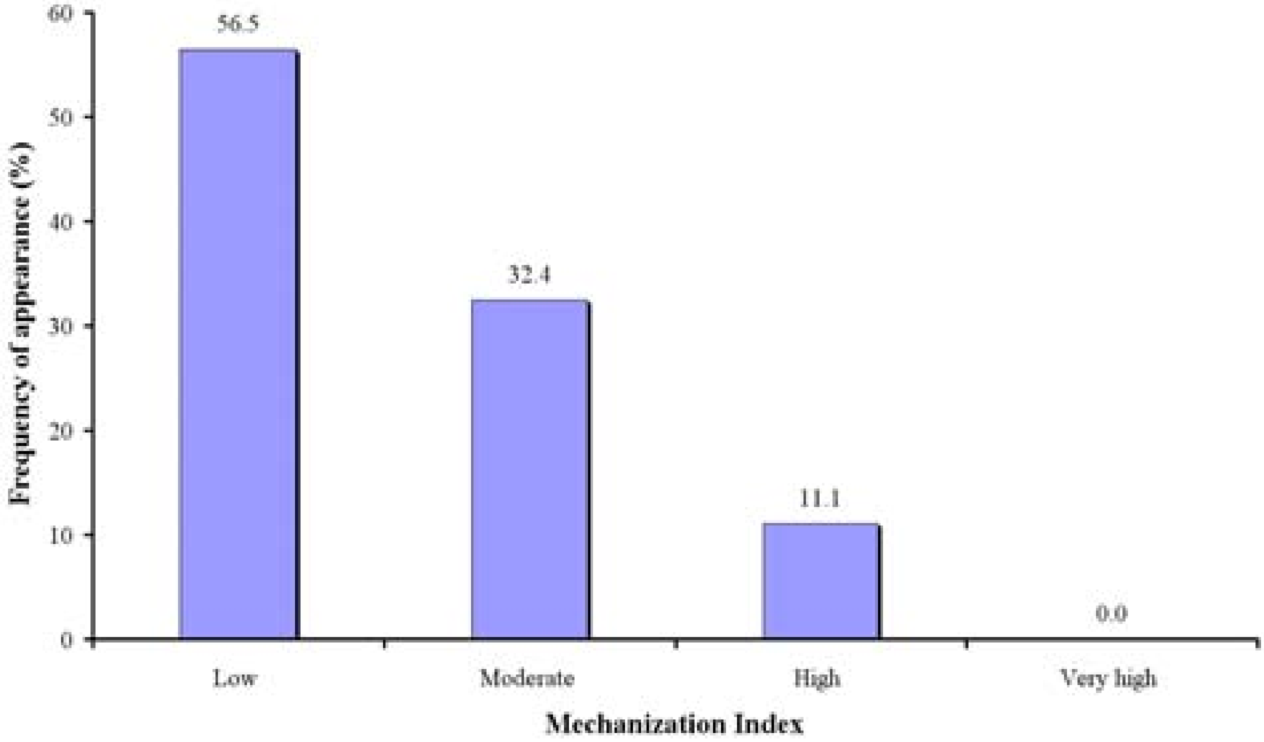

Fig. 64. Distribution of mechanization index defined in the study field sites

Grazing control

Grazing control is a management action aiming at the establishment of equilibrium between herbivores and the resource base of rangelands so that sustained production is ensured. This equilibrium suggests that animal grazing should be practiced so that range condition is maintained at a productive state and rangelands stay healthy. Generally, there are two main systems of grazing a land, namely: (a) continuous, and (b) rotational. In the continuous grazing system, animals remain throughout the grazing land during whole growing period or all the period of the year (Fig. 65). Such a system is beneficial to the animals since they are free to walk around and to select the best plants or plant parts available in the pasture. However, such a system is detrimental for the pasture since plant species do not have the chance to recover and in many cases soil remains partially covered by vegetation for protecting it from the raindrop impact. On the opposite, a rotational grazing system, involves division of the grazing land in pieces allowing the animals graze sequentially over the growing season of the year. Such a grazing control system allows the vegetation to recover and to protect soil from erosion. The following actions have been considered as controlled grazing for this project: (a) selection of a sustainable number of grazing animals, (b) fencing of grazing land and alternatively grazing, (c) avoidance of grazing when soils are very wet, (c) fire protection of grazing land, and (d) other specified. The existing grazing system in each study field site was identified by conducting the land owner.

 

Fig. 65. Grazing land under continuous grazing subjected to high vegetation degradation and soil erosion (left) and land under the same soil, topographic characteristics but under overgrazing and sustainable grazing systems (right)

As Table 9 shows, data for this indicator have been collected in 1141 field sites, corresponding to 14 study sites. The prevailing grazing system in the study field sites was no grazing control, covering 57.7% of the total fields (Fig. 66). Such grazing system has been identified in the all study sites of Mação- Portugal, Konya Karapinar plain-Turkey, and Eskisehir Turkey, and in several cases in the study sites of Secano Interior-Chile, Cointzio Catchment-Mexico, Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Novij Saratov-Russia, and Crete-Greece. Sustainable number of animals have been defined almost in the rest of the study field sites (35.3% of the total fields), corresponding to all study fields of Guadalentin Basin Murcia-Spain and in some field sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Gois-Portugal, Zeuss Koutine-Tunisia, Novij Saratov-Russia, Djanybek-Russia, and Crete-Greece. Other grazing systems such as fencing has been identified in few cases (6.0% of the total fields) corresponding mainly in the study sites of Secano Interior-Chile, Boteti Area-Botswana, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece.

Table 9. Number of field sites in which indicators related to husbandry was recorded in the filled questionnaires

site no	Study site	Number of field sites described for the indicator	
		Gra zing control	Grazing Intensity
1	Rendina Basin, Basilicata, Italy	-	-
2	Loess Plateau, China	-	-
3	Nestos Basin, Maggana, Greece	-	-
4	Secano Interior, Chile	28	28
5	Gois, Portugal	30	30
6	Mação, Portugal	31	31
7	Boteti Area, Botswana	49	49
8	Djanybek, Russia	69	69
9	Eskisehir, Turkey	70	70
10	Konya, Karapinar plain, Turkey	74	74
11	Novij, Saratov, Russia	84	84
12	Cointzio Watershed, Mexico	87	87

13	**Santiago Island, Cape Verde**	**103**	**103**
14	**Zeuss-Koutine, Tunisia**	**120**	**120**
15	**Mamora/Sehoul, Morocco**	**120**	**120**
16	**Guadalentin Basin, Murcia, Spain**	**121**	**121**
17	**Crete, Greece**	**155**	**155**
	TOTAL	**1141**	**1141**

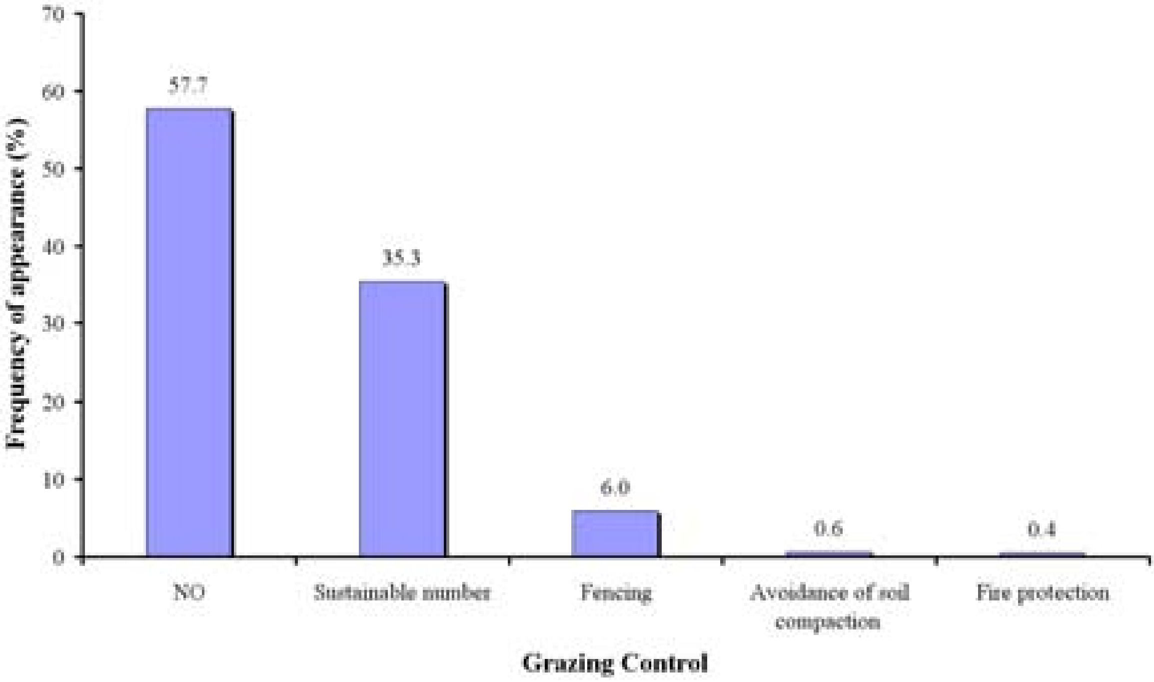

Fig. 66. Distribution of grazing control systems identified in the study field sites

Grazing intensity

It is a measure of the pressure imposed on the growing vegetation by the grazing animals. The number of animals is the main factor that affects the bioproductivity of the grazed lands. A standard way to express this impact is to calculate the stocking rate, namely the number of animal units per unit area during the grazing period. If the stocking rate in a grazing land is higher than its grazing capacity then overgrazing occurs (Fig. 67). An overgrazing land is vulnerable to desertification if the high number of animals remains for long period in the pasture and there is adverse soil, topographic and climatic conditions.

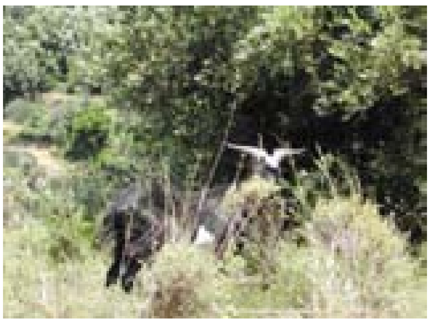

Fig. 67. Grazing land under high (left, Botswana) and low stocking rate (right, Crete) subjected to high and low desertification risk, respectively

The assessment of stocking rate has been assessed in this project by calculating the stocking rate (SR) and the grazing capacity (GC) and comparing these two values. If SR equals GC the rangelands are properly grazed, but if SR does not equal GC then grazing is improper and irrational and should be adjusted. The corresponding formulas for calculation are:

$$SR= \frac{\text{Number of grazing animals (SE)}}{\text{Area grazed (ha)}}$$

$$GC= \frac{\text{Area grazed (ha) X maximum forage production (kg/ha)}}{\text{Monthlyequ ivalents of a SE (Kg) X Grazing period (months)}}$$

one sheep equivalent (SE) = 1 sheep = 0,8 goats = 0,2 cattle. The following classes have been used: (a) low grazing intensity (SR<GR), (b) moderate grazing intensity (SR = GC to 1.5GC), and (c) high grazing intensity (SR>1.5GC).

As Table 9 shows, data for this indicator have been collected from 1141 field sites, corresponding to 14 study sites. The prevailing class of grazing intensity in the study field sites was low, that means the stocking rate was lower than the grazing capacity, covering 53.7% of the total fields (Fig. 67). Such grazing intensity was defined in all study fields of Novij Saratov-Russia, and Guadalentin Basin Murcia-Spain, and in some fields of Secano Interior-Chile, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Djanybek-Russia, Cointzio Catchment-Mexico, Gois-Portugal, and Crete-Greece. The next important class of grazing intensity was high, covering 33.2% of the study field sites, and corresponding to the study sites of Interior-Chile, Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Djanybek-Russia, and Crete-Greece. Finally, moderate grazing intensity has been defined only in 12.4% of the total field sites, corresponding to the sites of Secano Interior-Chile, Gois-Portugal, Boteti Area-Botswana, Eskisehir-Turkey, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Djanybek-Russia.

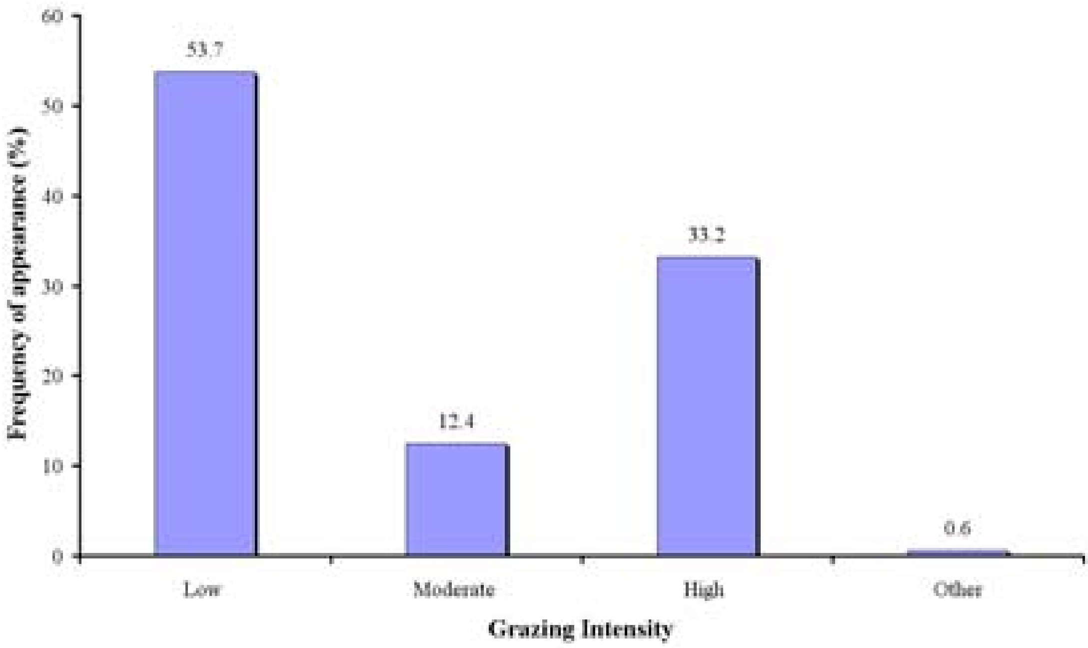

Fig. 68. Distribution of grazing intensity classes identified in the study field sites

2.10 Indicators related to land management

As it was mentioned in the introduction, the impacts of land degradation can be faced by responding with appropriate measures and land management practices. There is no doubt that soil erosion is the major land degradation process in hilly areas of the study sites. In most cases, this process is not controlled by a single land management practice but by a number of actions such as sustainable farming, land terracing, fire protection, enhancing vegetation cover, improving soil aggregate stability, etc. Sustainable farming may include practices such as conservation tillage, contour rotational farming, and incorporation of plant residues into the soil for improving aggregate stability. Terracing is an alternative land management practice for water conservation and erosion control. Vegetated areas comprise an effective sediment filter, usable in agricultural and other lands. Many areas cannot be efficiently cropped or, if cropped, are extremely susceptible to soil erosion. Areas with high rain erosivity index require maintenance of adequate vegetation cover during the rainy season. The conditions, in such areas, are aggravated by frequent fires, which have recently intensified in the Mediterranean Europe. An effective measure that might combat further land degradation is the development of alternative environmentally sound and socially tolerable land use schemes. These schemes should be implementing zoning in each threatened area, taking into consideration climatic, soil topographic, and social characteristics. Areas facing problems of salinization, acidification, and heavy metal contamination require reclamation in order to support efficiently the growing vegetation. In this project the following indicators related to land management for combating desertification have been considered: (a) fire protection, (b) sustainable farming, (c) reclamation of affected areas, (d) reclamation of mining areas, (e) soil erosion control measures, (f) soil water conservation measures, and (g) land terracing.

<u>Fire protection</u>

This indicator is related to the existence of protective infrastructures against forests fires and managed natural resources. The indicator contributes to the definition of the level of control and protective management against forest fire in a territory affected by desertification processes over a long period. It has been assessed by calculating the ratio between surface of forest and other wooded land designated or planned to be protected by infrastructures and natural resources managed against fire vs. the total territorial surface area. Data have been collected from the local Forestry Department administration. The following classes have been distinguished: (a) no protection, (b) low protection, < 25 % of total surface protected/total territorial surface; (c) moderate protection, 25-50 % of total surface protected/total territorial surface; (d) high protection, 50-75% of the total surface protected/total territorial surface; (e) very high protection, >75% of total surface protected/total territorial surface.

Table 10. Number of field sites in which indicators related to land management was defined in the filled questionnaires

		Number of field sites described for the indicator						
	Study site	Fire protection	Sustainable farming	Reclamation of affected Areas	Reclamation of mining areas	Soil erosion control	Soil water conservat.	Terracing
1	Nestos Basin, Maggana, Greece	-	-	30	-	-	-	-
2	Rendina Basin, Basilicata, Italy	-	-	-	-	30	-	30
3	Gois, Portugal	30	-	-	30	30	-	-
4	Mação, Portugal	31	-	-	31	31	-	-
5	Secano Interior, Chile	28	28	-	28	28	28	28

6	**Boteti Area, Botswana**	**49**	**2**	**7**	**18**	**52**	**40**	**48**
7	**Konya, Karapinar plain, Turkey**	**74**	**-**	**-**	**-**	**74**	**74**	**74**
8	**Loess Plateau, China**	**-**	**-**	**-**	**-**	**150**	**-**	**150**
9	**Djanybek, Russia**	**69**	**-**	**69**	**29**	**69**	**69**	**69**
10	**Eskisehir, Turkey**	**70**	**70**	**-**	**70**	**70**	**70**	**70**
11	**Cointzio Watershed, Mexico**	**87**	**67**	**-**	**87**	**87**	**67**	**67**
12	**Novij, Saratov, Russia**	**84**	**22**	**38**	**84**	**84**	**84**	**84**
13	**Guadalentin Basin, Murcia, Spain**	**121**	**121**	**-**	**0**	**121**	**121**	**121**
14	**Santiago Island, Cape Verde**	**103**	**103**	**-**	**103**	**103**	**103**	**103**
15	**Zeuss-Koutine, Tunisia**	**120**	**120**	**-**	**120**	**101**	**120**	**120**
16	**Mamora/Sehoul, Morocco**	**120**	**120**	**-**	**120**	**120**	**120**	**120**
17	**Crete, Greece**	**155**	**155**	**114**	**0**	**155**	**155**	**155**
	TOTAL	**1141**	**808**	**258**	**720**	**1305**	**1051**	**1239**

As Table 10 shows, data on fire protection have been collected in 1141 study field sites, corresponding to 14 study sites. The dominant class of fire protection was no measures for protection at all, covering 69.1% of the study field sites. Such fire protection conditions have been defined in the all field sites of the study sites: Boteti Area-Botswana, Santiago Island-Cape Verde, Eskisehir-Turkey, Konya Karapinar plain-Turkey, Djanybek-Russia, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico and Mação- Portugal, and in few field sites of Secano Interior-Chile, Novij Saratov-Russia, Gois-Portugal, and Mamora Sehoul-Morocco. Probably in some study sites such as Novij Saratov-Russia, and Djanybek-Russia, fire protection measures were not so necessary since the climatic conditions do not favor fires. Low fire protection measures have been defined in few field sites, covering 13.7% of the total cases, and corresponding in all study fields of the study sites of Guadalentin Basin Murcia-Spain, and in few cases in the study sites of Secano Interior-Chile, Gois-Portugal, and Mamora Sehoul-Morocco. Moderate measures for fire protection have been defined in 12.9% of the study field sites, corresponding to the study sites of Mamora Sehoul-Morocco, and Crete-Greece. Finally, high and very high measures for fire protection has been defined in very few cases 1.3% and 3.1%, respectively, corresponding to the study sites of Novij Saratov-Russia, Mamora Sehoul-Morocco, and Crete-Greece.

Sustainable farming

Sustainable farming is defined as an agricultural system evolving towards greater human utility, increased efficiency of resource use, minimum depletion of non-renewable resources, and environmental interaction favourable to humans and to most other species. Sustainable farming may include actions such as: (a) land utilization schemes within the land capability limits, (b) no minimum tillage, (c) enhancing vegetation cover, (d) tillage of soil in the up-slope direction, (e) minimum depth of ploughing, etc (Fig 70). Minimum tillage may have favourable effects on soil aggregation and reduction of soil crusting and soil erosion. If the soil moisture level is optimal, a minimum tillage is generally favourable because the implements break up the clods, incorporate the organic matter into the soil, kill weeds, and create a more favourable seed bed. Therefore, tillage is considered necessary in the normal management of some soils. However, frequent tillage operations, especially those involving heavy equipments, have detrimental effects on surface soil degradation such as accelerating oxidation of soil organic matter, breaking down stable soil aggregates. Maximum soil degradation occurs when a soil is tilled with a mouldboard plough followed by several disking. In a no-till system, the residues are concentrated on the soil surface enhancing aggregate stability and protecting the soil from erosion. Enhancing vegetation cover comprises an effective sediment filter, usable in agricultural and other lands. Irregularly shaped and unproductive dry areas can be kept under natural vegetation for controlling runoff and sediment loss. The type of sustainable farming (if any) has been defined for each study field site by identifying the measures undertaken for sustainable farming as delineated.

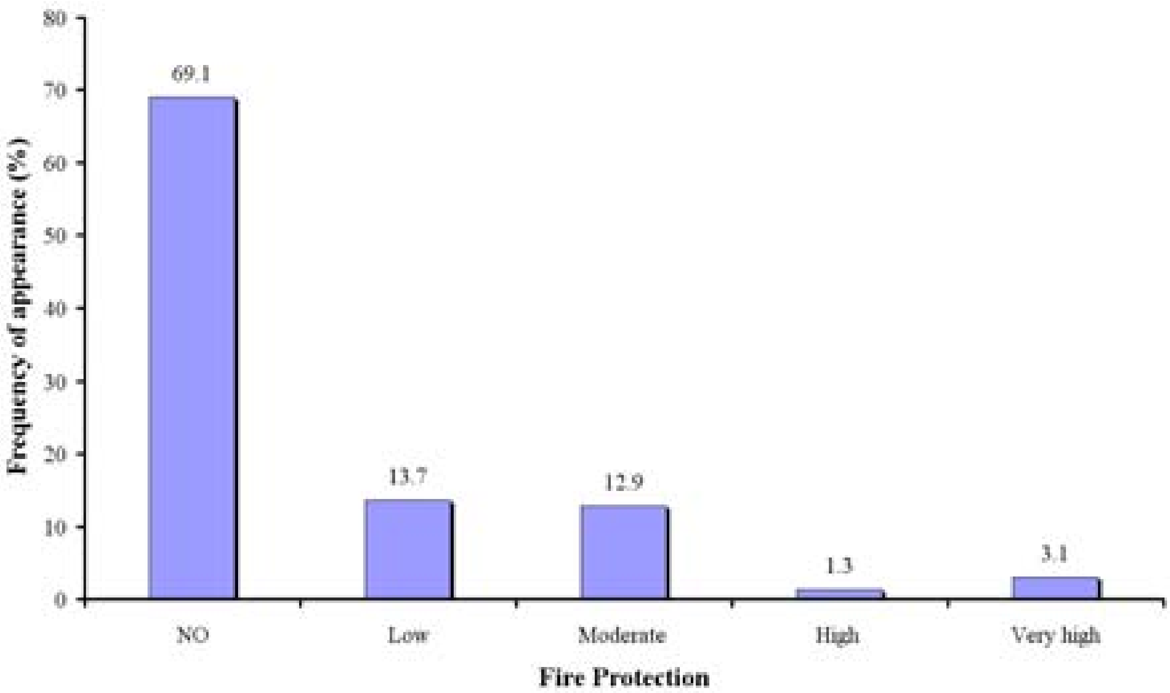

Fig. 69. Distribution of fire protection classes defined in the study field sites

Fig. 70. Examples of sustainable farming including no tillage (left) and minimum tillage-inducing plant cover (right)

Data for the indicator sustainable farming have been collected in 808 field sites, corresponding to 10 study sites. As Fig. 71 shows, no sustainable was defined in the majority of the study fields sites (53.8% of the total fields), corresponding to all field sites of Guadalentin Basin Murcia-Spain, Boteti Area-Botswana, Eskisehir-Turkey, Cointzio Catchment-Mexico, and Novij Saratov-Russia sites, and in some cases of Secano Interior-Chile, Mamora Sehoul-Morocco, and Zeuss Koutine-Tunisia sites. The next important action of sustainable farming was no tillage, defined in 21.0% of the study field sites. Such land management practice of sustainable farming has been identified in some cases in the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, and Crete-Greece. Minimum tillage as sustainable farming has been found in 14.0% of the study field sites, corresponding to the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece. Minimum depth of plowing has been defined in 8.4% 0f the study field sites, corresponding to the study sites of Secano Interior-Chile, Mamora Sehoul-Morocco, and Zeuss Koutine-Tunisia. Finally, land management practices of sustainable farming inducing plant cover, and up-slope tillage have been defined in very few cases (Fig 71), corresponding in the study sites of Secano Interior-Chile, and Zeuss Koutine-Tunisia.

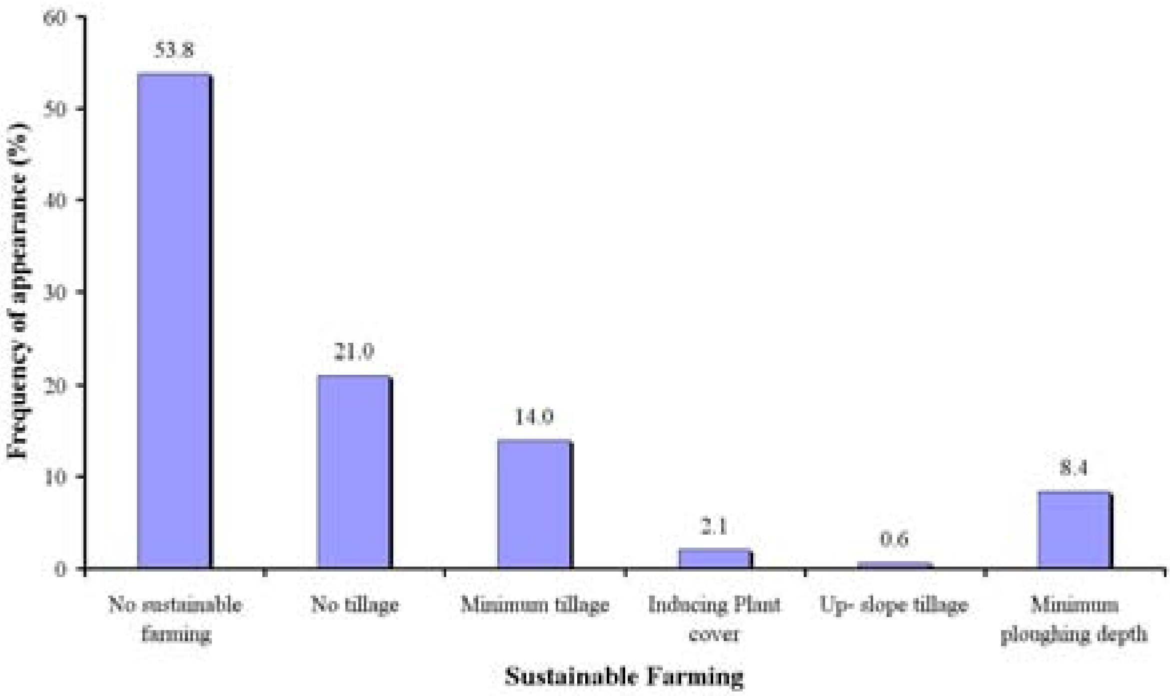

Fig. 71. Distribution of the various land management practices applied for sustainable farming in the study field sites

Reclamation of affected areas

According to UNCCD, the main processes included in National Action Plans as leading to desertification are soil erosion, acidification, salinization and heavy metal contamination. Due to the great importance of soil erosion to desertification, it has been considered separately in other indicators such as sustainable farming, soil erosion control measures, etc. Soils affected by acidification, salinization or heavy metal contamination are considered here as affected areas sensitive to desertification. Such areas can be reclaimed by applying various techniques depending on the degradation process. Salt-affected areas can be reclaimed by irrigating with excess of good water quality accompanied by an effective drainage network for lowering ground water table. Soil acidification is mainly resulting from intensification of agriculture using high amounts of acidifying fertilizers accompanied with irrigation. Old alluvial terraces or areas with soils formed on acid parent materials show a rapid soil fertility degradation and productivity depression. Acidified soils can be reclaimed by applying calcium in the form of calcium oxide or calcium hydroxide (Fig. 71). Heavy metal contaminated soils results form local sources of contamination such as industries, metal mining, wastes disposal, etc; and diffuse contamination from the atmosphere, cars, and certain agricultural practices.

This indicator has been assessed qualitatively subject to personal judgment or by measuring electrical conductivity of the soil for salt affected soils, concentration of available heavy metals for contaminated soils, and soil pH for acidified soils. The following categories of reclamation of affected areas have been used for this project: (a) no reclamation, (b) adequate drainage, (c) adequate salt leaching, (e) adequate liming of acidified soils, (f) low heavy metals availability.

Fig. 71. Examples of reclamation of salt affected by constructing a drainage network for lowering ground water (left) and acidified soils by applying calcium-magnesium hydroxide (right)

Data for this indicator have been collected from a limited number of field sites (258 fields), corresponding to 5 study sites. The obtained data have shown that no reclamation has been conducted in 95.3% of the affected areas described. The areas identified were mainly affected by salts, corresponding to the study sites Nestos Basin Maggana-Greece, Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, and Crete-Greece. Reclamation of affected areas has been identified in few cases covering 4.7% of the study field sites. These cases have been defined in the study site of Crete-Greece.

<u>Reclamation of mining areas</u>

Mining areas for extracting inert materials for buildings or metals have been extended particularly in dense populated areas in which several times the ground surface remains bare favouring surface water runoff and creating adverse microclimatic conditions. Mining areas must be progressively reclaimed by transporting soil, and covering the exposed bedrock or inert materials for planting species existing in the surrounding area (Fig. 72). Reclamation of mining areas has been defining by evaluating the measurements undertaken for soil erosion control such as terracing, vegetation cover, etc. The following classes have been distinguished for this project: (a) no actions undertaken, (b) low, incomplete protection, less than 25% of the area is protected; (c) moderate, partial protection, 25-75% of the area is protected; (d) adequate, complete protection, >75 of the area is protected.

As Table 10 shows, data for this indicator have been collected for 720 field sites, corresponding to 13 study sites. Data have been provided from the following study sites: Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Cointzio Catchment-Mexico, Gois-Portugal, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Eskisehir-Turkey. The analysis of the data has shown that no actions have been undertaken for erosion control measures in all study field sites. Probably there might have been overexpectations from this indicator or a misunderstanding in collecting such data related to the not so common reclamation of mining areas.


Fig. 72. Examples of mining areas without any reclamation action (left) and reclaimed after mining activities have been finished (right)

Soil erosion control measures

Soil erosion control measures includes actions undertaken to reduce soil erosion caused by various factors such as surface water runoff, tillage operations, wind blowing, etc. Soil erosion control measures may include: conservation tillage, contour farming, stabilization structures, vegetated waterways, strip cropping, enhancement of understory growing vegetation, adequate plant cover, terracing, small water reservoirs, etc. Conservation tillage is a land management practice which can significantly reduces rill and interill erosion in hilly areas cultivated with annual crops. The incorporation of plant residues into the soil after harvesting increases soil organic matter content and improve soil aggregate stability.

Contour farming is considered a very effective practice for reducing soil erosion, but in many cases farmers faces security problems when slope gradient is greater than 12%. Following the contour farming, each furrow acts as a reservoir to receive and retain runoff water. However this type of ploughing can led to accelerated soil erosion and deposition in the lowland. Following the contour farming, each furrow acts as a reservoir to receive and retain the runoff water. On long length slopes and under heavy and prolonged rainfall events, contoured rows can cause considerable rilling or gulling.

Stabilization structures protect soil erosion in channels where water is concentrated. Such structures reduce runoff water velocity to non-erosive rates. Such structures can be are permanent consisting of reinforced concrete or monolithic reinforced concrete such as drop spillways, drop inlets, as well as temporary structures made of rocks, logs, brush, woven wire and other nondurable materials to dissipate the energy of falling water (Fig. 73).

Enhancement of understory annual vegetation is an appropriate land management for reducing soil erosion in hilly areas cultivated with perennial crops such as olives, vines, almonds, etc (Fig 73). Many studies have been shown that such vegetation cover reduces soil erosion to minimum values. The only dispute for this management practice is the adsorption by this vegetation of an amount of soil water stored in the upper soil layers. This soil erosion control measure can be combining with vegetated waterways in which soil erosion is expected to be limited.

Terracing is an alternative management practice for water conservation and erosion control. Terracing decreases the slope length and reduces the damage by surface water runoff Fig. 74). It is actually a very old practice having been used for centuries in many places of the world.

Fig 73. Temporal stabilization structure for reducing water runoff in channel to non0erosive rates (left) and enhancement of understory vegetation for reducing soil erosion after a fire in a olive grove (right)

Strip cropping is a practice in which hilly areas are not cultivated uniformly with the same crop. There are alternative strips with various crops growing in different period. Therefore, if runoff occurs form one field which is not well vegetated then this water is trapped in next field which is well vegetated. Furthermore, Small water reservoirs are constructed at farm level or in collaboration of nearby farmers. Water is temporarily stored into the reservoir reducing down slope water runoff (Fig 74).

Fig. 74. Small terraces vegetated to reduce accelerated erosion (left) and small water reservoir for temporal storage of water runoff

The efficacy of the existing soil erosion control measures have been defined in this project based on a self explanatory estimation as following: : (a) no actions undertaken, (b) low, incomplete protection, less than 25% of the area is protected; (c) moderate, partial protection, 25-75% of the area is protected; (d) adequate, complete protection, >75 of the area is protected.

As Table 10 shows, data for this indicator have been collected in 1305 field sites, corresponding to 16 study sites. The analysis of the data shows that in the majority of the study field sites (74.2% of the total sites) no soil erosion measures have been undertaken. Of course such land management practices are very negative in combating land degradation in areas sensitive to desertification. Such conditions have been defined in all study sites of Novij Saratov-Russia, Eskisehir-Turkey, Rendina Basin Basilicata-Italy, and Loess Plateau-China, and in some cases in the study sites of Boteti Area-Botswana, Djanybek-Russia, Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Mação- Portugal, Guadalentin Basin Murcia-Spain, Cointzio Catchment-Mexico, Gois-Portugal, and Crete-Greece. Low soil erosion control measures have been identified in 14.3% of the study field sites, corresponding to the study sites of Djanybek-Russia, Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, and Konya Karapinar plain-Turkey, Mação- Portugal, Cointzio Catchment-Mexico, Gois-Portugal, and Crete-Greece. Adequate measures of soil erosion control have been defined in 7.7% of the study field sites, corresponding to the study sites of Boteti Area-Botswana, Secano Interior-Chile, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, and Crete-Greece. Finally, moderate measures for soil erosion control have been found only in 3.8% of the study field sites, corresponding in few cases in the study sites of Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece.

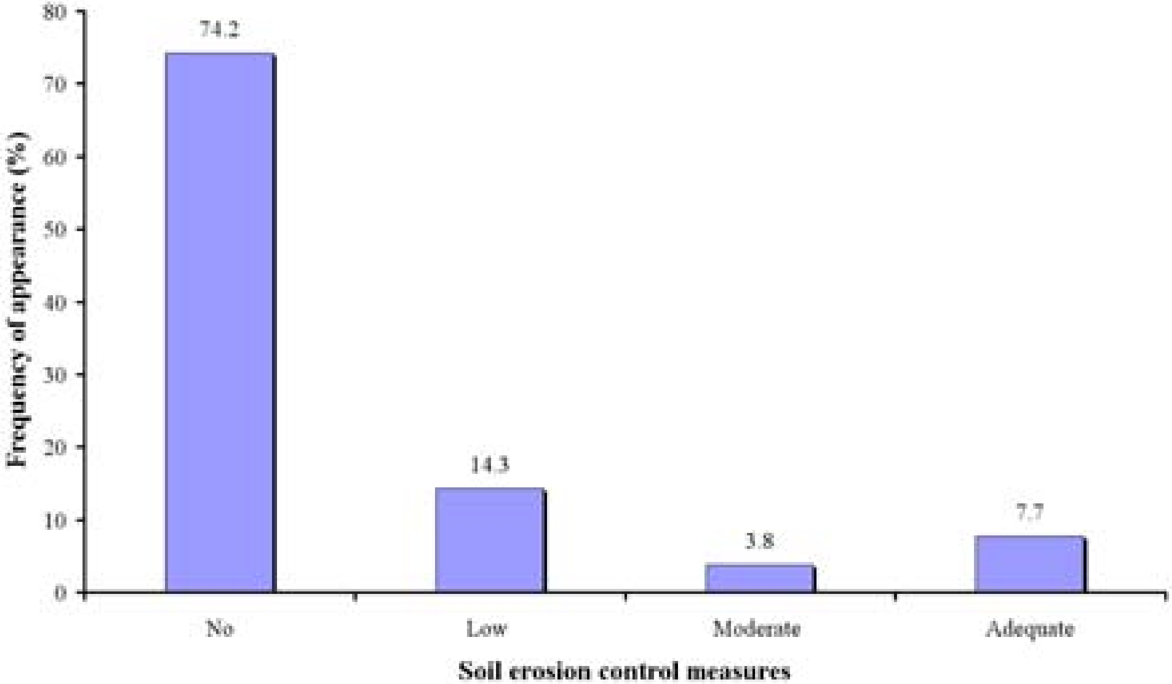

Fig. 75. Distribution of soil erosion control measures defined in the study field sites

<u>Soil water conservation measures</u>

Soil water conservation techniques may include the following: mulching, weed control, management of soil surface for maximum water infiltration and vapour adsorption, cultivation, etc. Weed control usually takes place by means of mechanical tillage or chemical sprays such as glyphosate, paraquat, etc., whereas mulching or grazing is alternatively applied in organic farming. Grazing is the removal of entire plants or parts of them by herbivores in order to feed themselves (Fig. 76).

Considering that the amount of rain occurring under arid or semi-arid climatic conditions are compared to the evapotranspiration rates during the dry period (May-October), water vapour adsorption becomes one of the most important sources of available water at least for the growing annual vegetation. Under such climatic conditions, soil physical characteristics such as surface mulching, and density of the growing plants greatly affect water vapour adsorption and soil water conservation. Management of the land by: (a) reducing the density of the growing vegetation and increasing the soil-atmosphere interface, (b) using surface mulches such as rock fragments or plant residues partially covering the soil surface, and (d) ploughing the soil for increasing macro porosity can beneficially and significantly affects water vapour adsorption and soil water conservation. The existing techniques on soil water conservation are recorded for each study site.

Fig 76. Examples of controlling weeds by using herbicides (left) and grazing (right)

Cultivation of the land using various tillage implements such as mouldboard, chisel, duck foot chisel, harrow, etc is considered as a management practice for conserving subsoil water However, ploughing the soils in hilly can cause severe problems of land degradation due to mechanical displacement of soils usually down slope (Fig. 77).

Fig. 77. Examples of water conservation by ploughing the soil (left) and keeping dry leaves as mulching on the soil surface (right)

Data for this indicator have been collected in 1051 field sites, corresponding to 12 study sites (Table 10). Soil water conservation measures have not defined in 58.2% of the study field sides, corresponding to all cases of the study sites Boteti Area-Botswana and Eskisehir-Turkey, and in some cases in the study sites of Djanybek-Russia, Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico and Crete-Greece. Soil water conservation measures such as mulcting, weed control, etc., have been defined in 41.8% of the study field sites, corresponding to all cases of the study sites of Konya Karapinar plain-Turkey, Novij Saratov-Russia, and Eskisehir-Turkey, and in some cases of the study sites of Djanybek-Russia, Secano Interior-Chile, Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Crete-Greece.

<u>Presence of terracing</u>

Terraces are constructions built mainly in hilly areas to reduce water erosion losses from cultivated erodible soils and for water conservation. Terracing of hilly areas is a measure to combat desertification. Adsorption of water by the soil increases during heavy rainfall events and soil erosion is reduced in terracing land. If terraces are well designed, terraces control sheet and gully erosion by reducing slope length. Water runoff from the upper side of the terraced interval is held within the terrace, infiltrates and it is stored in the soil. Land terracing is the construction of relatively flat surfaces of reasonable size to allow cultivation of sloping areas. It is accomplished by removing strips of soil parallel to contours lines and accumulating the removed material over the soil surface just below the trench, transforming the natural slope in a stair-like anthropogenic environment. Techniques of terrace construction have been changed through centuries. In early practice, the land was shaped into a series of nearly level benches or step-like formations bounded on the lower side by an almost vertical bank usually protected by a stone wall. Modern practice in terracing, however, consists of nearly level benches constructed using machines which are wide enough to be cultivated, seeded, and harvested with ordinary machinery (Fig. 78).

Fig. 78. Examples of traditional (left) and modern (right) land terracing

Terracing is not a natural sustainable land utilization type. Therefore, it must be properly constructed and effectively maintained, taking in consideration slope gradient and length, soil parent material and depth, avoiding exposure of highly erodible and undesirable materials. Above all economic sustainability of the terraced land must be secured for long periods of time. Otherwise, it may cause high soil erosion rates and fast and severe deterioration of land.

The assessment of land terracing has been conducted by the extent in which an area is covered by terraces. It has been defined as the ratio of the area protected to the total area, expressed as a percentage using the following classes: (a) no terracing, (b) low, <25% of the area is protected; (c) moderate, 25-50% of the area is protected; (d) high, 50-75% of the area is protected; (e) very high, >75% of the area is protected. The assessment has been made by: (a) simple field observations, or (b) aerial photography interpretation.

As Table 10 shows, data for this indicator have been collected in 1239 study sites, corresponding to 14 study sites. No land terracing has been identified in 85.5% of the study field sites (Fig. 79). None field sites with terracing has been defined in the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Secano Interior-Chile, Rendina Basin Basilicata-Italy, Mamora Sehoul-Morocco, Eskisehir-Turkey, Cointzio Catchment-Mexico, and Konya Karapinar plain-Turkey, while no terracing has been defined in most of the cases of the study sites Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, Loess Plateau-China, and Crete-Greece. All the other classes of land terracing (Fig. 79) have been found in less than 14.5% of the study field sites. The most important action for soil erosion control and water conservation using terraces has been identified in the following 4 study sites: Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Loess Plateau, China.

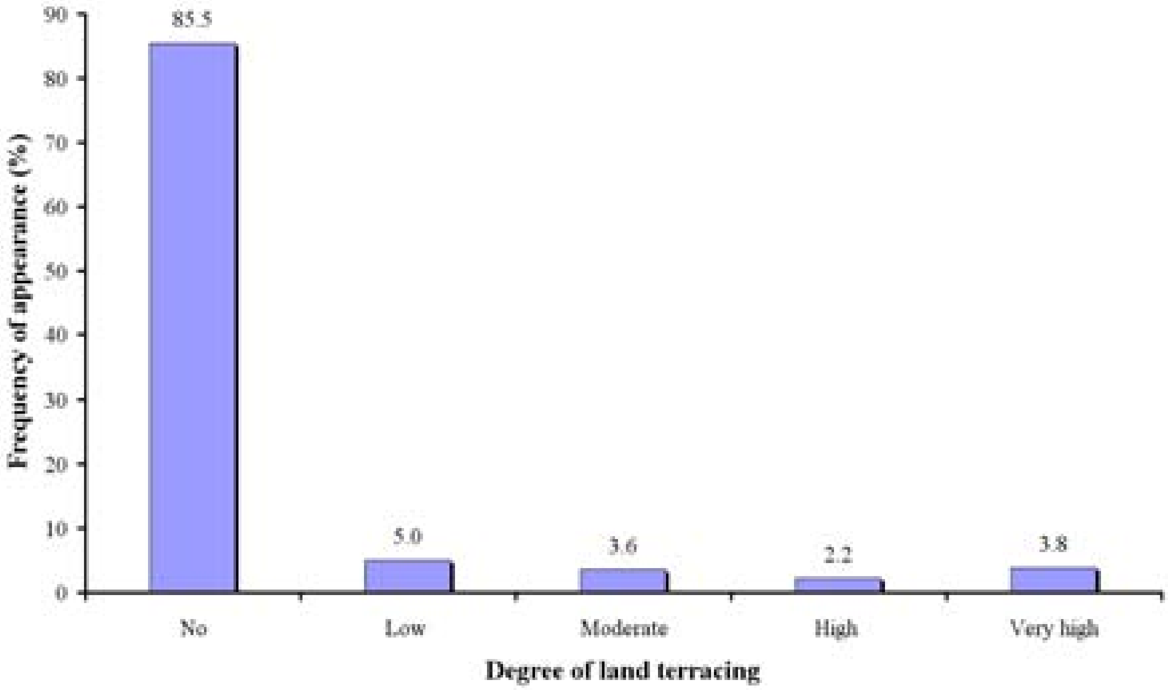

Fig. 79. Distribution of degree of land terracing defined in the study field sites

2.11 Indicators related to land use

Types of vegetation and land use are important factors controlling various processes affecting desertification. Land use and land use intensity is related to processes of land degradation and desertification such as soil erosion, soil structure decline, loss in organic matter content, soil salinization, etc. These processes are related to human actions such as repeated destruction of vegetation on the sloping lands, reduction in organic matter content and aggregate stability of soils, improper tillage operations, and irrigation with low quality water, without satisfying the leaching requirements.

The land use type and land use evolution is a very important factor for assessing the various processes of land degradation and desertification. Changes from sustainable traditional land uses to more intensive land uses steadily puts pressure on the soil initiating or enhancing land desertification processes often resulting in land abandonment. Various driving forces such as subsidies, new cultivation techniques, and availability of infrastructures have greatly affected land uses and land use changes with great impacts on land degradation and desertification.

Crop production in many hilly areas around the Mediterranean region has drastically declined due to soil erosion and cultivation is more and more concentrated in the most promising low lands. Some of the degraded hilly areas have been abandoned from agriculture and used as grazing land... Such areas are very often deliberately burned by farmers to eradicate the existing vegetation and encourage the growth of palatable grass, and then they are overgrazed favouring high erosion rates and subjected to high desertification risk. Others are naturally transformed into forest lands reducing desertification risk.

In the last decades urban areas have been extended in productive soils located along the coast of the Mediterranean basin. The process of urbanization accompanied by the expansion of infrastructures (roads, airports, ports, etc) leads to isolation of soil acting as a natural body affecting the physical environment. Urbanization have great impacts on various degradation processes such as soil erosion, flooding of lowland, reduction of groundwater enrichment with good quality of water, water pollution, etc.

The following indicators have been considered here related to land use: (a) land abandonment, (b) land use intensity, (c) period of existing land use, (d) urban area, (e) rate of change of urban area, (f) distance from the seashore.

Land abandonment

Land abandonment is related to decreasing land profitability, usually resulting in change land use from agriculture to grazing land. The extensive deforestation and intensive cultivation of hilly areas especially during the last decades has led to soil erosion and the formation of shallow skeletal soils. As the soil is eroded, land use is usually shifted from agriculture to pasture due to increasingly poor yields from the various agricultural crops. Such a pasture land in the Mediterranean region is defined as an abandoned land today. Various authors have simultaneously used the terms 'abandoned land' and 'grazing land', but grazing or hunting an abandoned land is considered a traditional use in the Mediterranean region. Land abandonment does not necessarily mean that land is no longer used, either by agriculture or any other rural economic activity. It means a change in land use from the traditional or recent pattern to another, less intensive pattern.

Land abandonment may have positive or negative impacts on desertification depending on the soils and climatic conditions of the area. Soils under favourable climatic conditions that sustain plant cover may improve with time by accumulating organic materials, increasing floral and faunal activity, improving soil structure, increasing infiltration capacity, and therefore decrease erosion potential and desertification risk (Fig. 80). On the contrary, areas with soils relatively shallow, of low organic matter content, with thin and of low resilience capacity vegetation cover, in steep slopes, with adverse climatic conditions, and overgrazed result in negative impacts of land abandonment (Fig. 80). The natural restoration processes in these areas are really slow, almost impossible, and persistent erosion processes can lead to severe soil degradation and desertification.

Fig. 80. Examples of areas with positive (left) and negative (right) effects of land abandonment

Data on land abandonment have been obtained from the National Statistical Services of the study sites or in consultation with the local cooperatives. The analysis of ortho-photomaps or satellite data has been also used. The rate of land abandonment has been expressed in hectares of land abandoned every 10 years on 10 km^2 territory. The following four classes of rate of land abandonment have been defined: (a) low-abandoned area <10 ha per 10 years per 10 km^2 of territory, (b) moderate-abandoned area 10-25 ha per 10 years per 10 km^2 of territory, (c) high- abandoned area 26-50 ha per 10 years per 10 km^2 of territory, and (d) very high-abandoned area >50 ha per 10 years per 10 km^2 of territory.

As Table 11 shows, data for this indicator have been collected in 1141 study field sites, corresponding to 14 study sites. As Fig. 81 shows, in the majority of the study field sites the rate of abandonment of the land in the around territory was low (<10 ha per 10 years per 10 km^2), covering

63.8% of the study sites. This rate of land abandonment has been identified in all cases of the study sites of Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, and Crete-Greece, and is some cases in the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Zeuss Koutine-Tunisia, Gois-Portugal, and Mação- Portugal. Moderate rate of land abandonment (10-25 ha per 10 years per 10 km^2) has been defined in 18.2% of the study field sites, corresponding to all cases of the study sites of Eskisehir-Turkey, Konya Karapinar plain-Turkey, and in few cases in Boteti Area-Botswana, Gois-Portugal, and Novij Saratov-Russia. High rate of land abandonment (26-50 ha per 10 years per 10 km^2) has been identified in 15.1% of the study field sites, corresponding to the study sites of Novij Saratov-Russia, Djanybek-Russia, and Guadalentin Basin Murcia-Spain. Very high rate of land abandonment (>50 ha per 10 years per 10 km^2) has been defined in few cases of the Zeuss Koutine-Tunisia study site (Fig. 81).

Table 11. Number of field sites in which indicators related to land use was defined in the filled questionnaires

	Study site	Number of field sites described for the indicator					
		Land abandonment	Land use intensity	Period of existing land use	Urban area (%)	Rate of change of urban area	Distance from seashore
1	Rendina Basin, Basilicata, Italy	-	30	-	-	-	-
2	Nestos Basin, Maggana, Greece	-	-	30	-	-	30
3	Gois, Portugal	30	30	-	-	-	-
4	Mação, Portugal	31	31	-	-	-	-
5	Secano Interior, Chile	28	28	28	-	-	-
6	Boteti Area, Botswana	49	26	35	9	9	7
7	Loess Plateau, China	-	150	-	-	-	-
8	Eskisehir, Turkey	70	70	70	-	-	-
9	Konya, Karapinar plain, Turkey	74	74	74	-	-	-
10	Cointzio Watershed, Mexico	87	87	67	-	-	-
11	Novij, Saratov, Russia	84	84	60	-	-	38
12	Djanybek, Russia	69	29	109	-	-	69
13	Santiago Island, Cape Verde	103	103	103	-	-	-
14	Mamora/Sehoul, Morocco	120	120	120	-	-	-
15	Zeuss-Koutine, Tunisia	120	120	120	-	-	-
	Guadalentin Basin, Murcia, Spain	121	121	121	-	-	-
	Crete, Greece	155	155	269	-	-	114
	TOTAL	1141	1258	1206	9	9	258

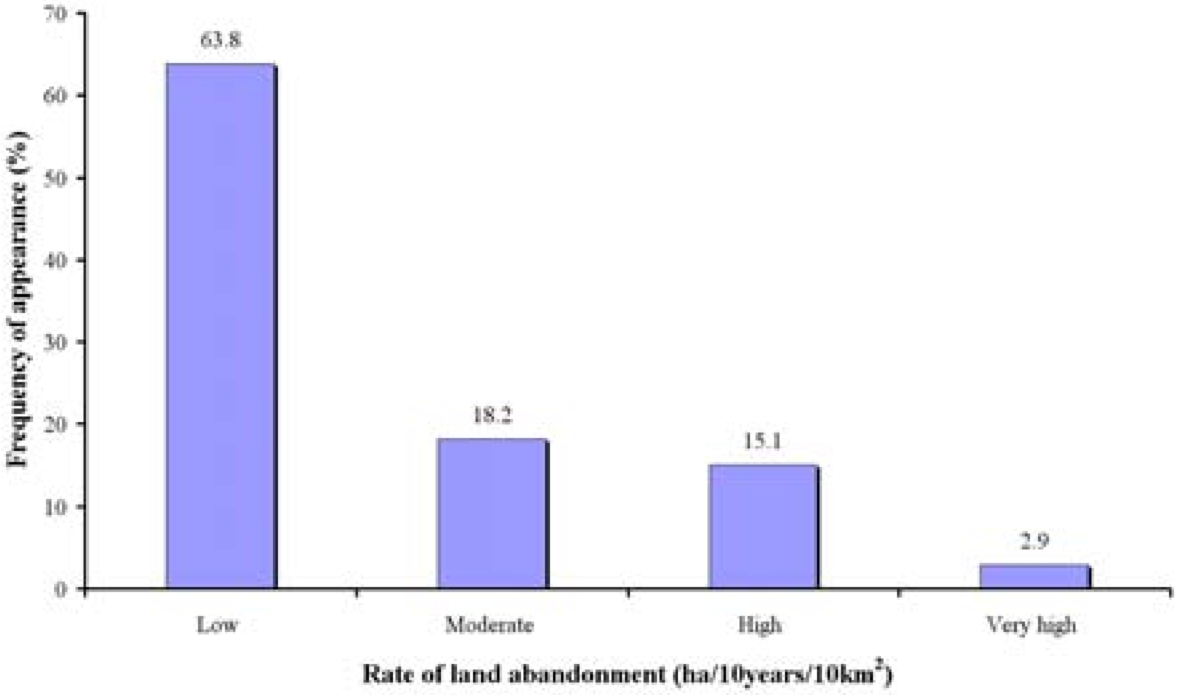

Fig. 81. Distribution of rate of land abandonment classes identified in the study field sites

Land use intensity

Land use intensity is referred to all types of land uses, agriculture, pastures, forests, etc. Land use intensity in cropland areas is related to the degree in which the cultivation of the land is mechanized, the application or not of fertilizers and pesticides, and finally the use of water for irrigation (Fig 82). Repeated cultivation of soils associated with other management practices (application of herbicides and pesticides) results in decreased organic matter content and aggregate stability favouring soil crusting, overland flow, and erosion. Soil compaction is also another form of soil degradation resulting from heavy machineries used in agricultural areas. In pastures, land use intensity is related to the number of animals grazing the land compared to the sustainable number of animals based on the amount of biomass production (Fig. 82). Intensive grazing results in loss of vegetation cover, degradation of soil structure due to animal trampling, favouring overland flow, and soil erosion.

Land use intensity in forested areas is related to yields in wood extraction compared to the sustainable wood extraction. In case that trees are removed in rate higher than the sustainable number stand density decreases gradually, then the soil is partially covered with vegetation and therefore from raindrop impact and soil erosion. In mining areas soils are usually disturbed with the bedrock or waste materials exposed in the surface. Such areas require rehabilitation by transporting and spreading soil for allowing the native vegetation to grow.

Recreation areas can be subjected to high number of visitors in certain period affecting soil surface in certain pathways. Some of the effects of many people walking in such areas are: destruction of annual vegetation, disturbance of soil aggregates, formation of pathways in which runoff water can concentrate and generating mainly gully erosion.

 

Fig. 82. Examples of intensive land use of agriculture area (left) and pasture (right)

Three classes of land use intensity are distinguished to: (a) low, (b) medium, and (c) high. The definition of each class is based on the type of land use. For each of the following land use types, the intensity of the use is assessed separately based on the MEDALUS III methodology:

- Agricultural land (cropland, pasture or rangeland)
- Natural areas (forests, shrubland, bare land)
- Mining land (quarries, mines, etc.)
- Recreation areas (parks, compact tourism development, tourist areas, etc.).

The land use intensity for cropland has been assessed by characterizing the frequency of irrigation, degree of mechanization, the use of agrochemicals and fertilizers, the crop varieties used, etc. Three levels of land use intensity are distinguished for the agricultural areas as following:

- Low land use intensity (extensive agriculture): Local rain fed plant varieties are used, fertilizers and pesticides are not applied, yields depend primarily on the fertility of soils and environmental conditions. Mechanization is limited. In the case of seasonal crops, one crop is cultivated per year or the land remains fallow.
- Medium land use intensity: Improved varieties are used, insufficient fertilizers are applied and inadequate disease control is undertaken. Mechanization is restricted to the most important tasks such as sowing.
- High land use intensity (intensive agriculture): Improved varieties are used. Application of fertilizers and control of diseases are adequate. Cultivation is highly mechanized.

The land use intensity for pasture land has been assessed by estimating the grazing capacity (GC) of the area and comparing it with the stocking rate (SR). The necessary formulas for assessing these values are given in the indicator “grazing intensity”. The intensity of use has been estimated by comparing the GC and the actual number of animals grazing the land (SR) and forming the ratio actual/sustainable. The following classes have been distinguished: (a) low (SR<GC), (b) moderate (SR = GC to 1.5*GC), and (c) high (SR>1.5*GC).

The assessment of land use intensity for natural land (forests) requires a major distinction between natural forests and managed forest. In the case of natural forests the land use intensity is considered low as there is by definition absence of any management. In the case of managed forests, the intensity of use has been determined by comparing the sustainable (S) and the actual (A) yield of the forest and forming the ratio actual/sustainable. The following classes are distinguished: (a) low (A/S = 0), (b) moderate (A/S <1), and (c) high (A/S = 1 or greater).

Mining activities have a highly degrading effect both during their lifetime and after the end of the mining. Hence, a primary distinction is made between active and inactive mining sites. For active site, the intensity of land use has been assessed as following: surface or subsurface mining with full rehabilitation and erosion monitoring and control will be considered as well managed (low land use intensity). Surface or subsurface mining with moderate rehabilitation and erosion monitoring and control will be rated with medium land use intensity. Surface or subsurface mining activities without rehabilitation and with minimum erosion monitoring, will be rated with high land use intensity.

The assessment of land use intensity in recreation areas requires the basic distinction between passive and active recreation, since these may cause a significant variation on the degree of stress on the land. Passive recreation, which is the least threatening to the environment, includes walking, nature seeing, mountain climbing, swimming and similar activities. Active recreation, which is more important for land degradation includes: skiing, cross country skiing games, sand rallies, motor racing etc. The assessment procedure has considered: (a) assessment of the visitor carrying capacity of the recreation area (maximum number of visitors permitted per year), (b) assessment of the actual number of visitors per year, (c) calculation of the ratio of actual to permitted number of visitors per year, (d) rating the quality of management as high if the ratio is equal or less than one, and as low if the ratio is greater than one.

Data for the indicator “land use intensity” have been collected in 1258 study field sites, corresponding to 16 study sites (Table 11). As Fig. 83 shows, low land use intensity was the next important class, covering 37.1% of the study field sites, and corresponding to study sites of Boteti Area-Botswana, Secano Interior-Chile, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Eskisehir-Turkey, Gois-Portugal, Cointzio Catchment-Mexico, Mação- Portugal, Loess Plateau, China, and Crete-Greece. High land use intensity has been identified in 33.1% of the study field sites, corresponding to the all cases of the study sites of Novij Saratov-Russia, Djanybek-Russia, and Konya Karapinar plain-Turkey, and in some cases in the study sites of Boteti Area-Botswana, Secano Interior-Chile, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Eskisehir-Turkey, and Crete-Greece. Finally, medium land use intensity has been identified in 29.8% of the study field sites, corresponding to all sites of Guadalentin Basin Murcia-Spain, and in some cases in the study sites of Boteti Area-Botswana, Cointzio Catchment-Mexico, Gois-Portugal, Novij Saratov-Russia, Secano Interior-Chile, Rendina Basin Basilicata-Italy, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Mação- Portugal, Loess Plateau, China, and Crete-Greece.

Period of existing land use

The present land use type, and the period of existence of that land use type, is an important indicator as it is related to cumulative long effects on land protection or on land degradation. The vegetation patterns which cover the landscape affect the soil in all its dynamics, including water redistribution over and within the soil, soil erosion, soil organic matter content, microbiological activity, etc. Of course other factors such as land use intensity, climate, topography, etc. have a variable effect on soil degradation. Long term experimental soil erosion studies conducted along the northern Mediterranean Europe under various land uses and exiting land management practices have shown the following average sediment loss range of soil erosion rates (Kosmas et *al*., 1997):

- Cereals: 15- 90 t km^{-2} yr^{-1}
- Vines: 67- 460 t km^{-2} yr^{-1}
- Eucalyptus: 1.4-65.6 t km^{-2} yr^{-1}
- Olives: nill-5.3 t km^{-2} yr^{-1}
- Shrubland: 0.5-13.8 t km^{-2} yr^{-1}.

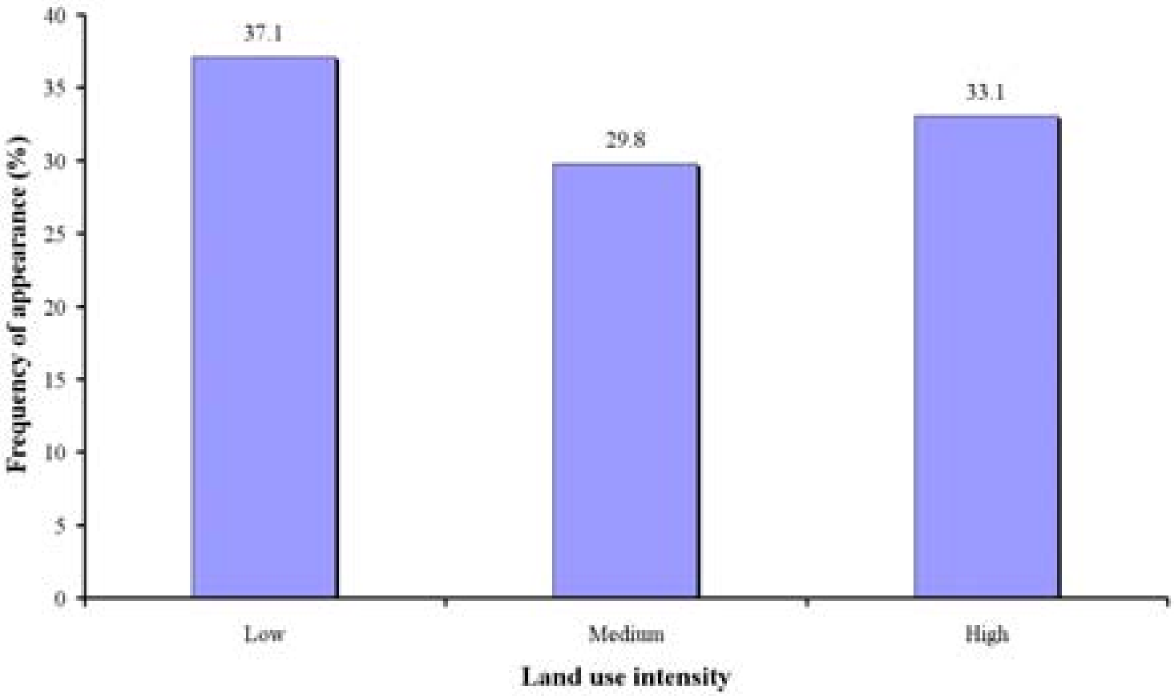

Fig. 83. Distribution of land use intensity classes identified in the study field sites

Therefore, land use type over a long period is clearly an important factor in controlling soil loss and desertification risk. As Fig. 84 shows, land use had a great effect on soil erosion and land degradation under pine forest, olive groves, and cereals replaced as grazing land after severe soil degradation in the island of Lesvos (Marathaniou *et al*., 2000). Clearing of pine forest and replacement with olive groves had no significant effect on land degradation. On the contrary, clearing of pine forest and replacing with cereals or grazed without applying sufficient measures for soil protection, land had largely degraded and desertified, with the present soil being unable to support adequate vegetation cover.

Fig 84. Typical example of long term effect of land use on land degradation under the same soil, topographic, and climatic conditions in which part of the pine forest (left) was cleared and replaced by olive grove (middle), and cereals followed by pasture (right)

The following 5 classes of period of land use have been defined for the purpose of this project: (a) period <5 years, (b) period 5-10 years, (c) period 10-20 years, (d) period 20-50 years, and

(e) period >50 years. The period of existing land use has been defined by contacting the land user or by interpretation of a chronological series of aerial photographs.

As Table 11 shows, periods of land use have been defined in 1206 field sites, corresponding to 13 study sites. The prevailing period of existing land use was greater than 50 years, covering 42.2% of the study sites, corresponding to the study sites of Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, Zeuss Koutine-Tunisia, Guadalentin Basin Murcia-Spain, and Crete-Greece (Fig. 85). The next important period class of existing land use was 20-50 years, covering 29.4% of the study field sites, corresponding to the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Secano Interior-Chile, Nestos Basin Maggana-Greece, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Crete-Greece. The period of 10-20 years of existing land use has been defined in 11.7% of the study field sites, corresponding to the study sites of Boteti Area-Botswana, Djanybek-Russia, Secano Interior-Chile, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, and Crete-Greece. A very short period of exiting land use (less than 1 year) has been identified in 11.4% of the study field sites, corresponding to the study sites of Novij Saratov-Russia, Eskisehir-Turkey, and Konya Karapinar plain-Turkey. The other period classes of existing land uses 1-5, and 5-10 years were identified in few cases, covering 3.7%, and 1.9% of the study field sites, respectively, and corresponding to the study sites of Novij Saratov-Russia, Secano Interior-Chile, Mamora Sehoul-Morocco, Guadalentin Basin Murcia-Spain, and Crete-Greece.

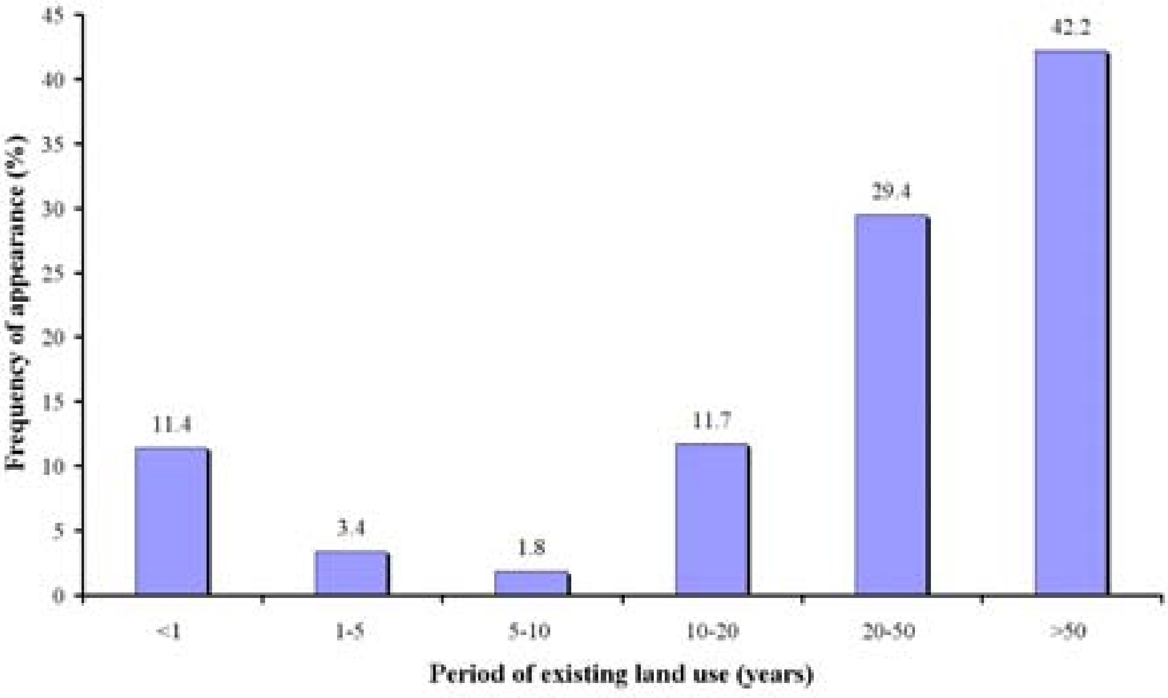

Fig. 85. Distribution of period of existing land use classes identified in the study field sites

Urban area and rate of change

Urban area and rate of change of urban area are two interrelated indicators, which are connected with the indicator of impervious surface discussed above. The extent of urban areas and rate of expansion are factors affecting soil sealing. Urban areas are widely expanded along the Mediterranean coastline in the last decades removing fertile soils from agricultural production and causing tremendous effects on ground water recharge, flooding, brackish water intrusion in aquifers, soil salinization, processes related to desertification. Furthermore, the current spreading of urban areas in wild lands has significantly affected frequency and extent of forest fires. This generates high ignition hazard from human activities to forest fuels, and high risk of forest fires affecting housings and other urban structures. Some countries have developed regulations to reduce fuels in the perimeter of the urban area and to use less flammable building materials in houses. Last summer (2009) a great forest fire occurred around the Athens urban area for which the main driver of destroying the pine forest was the illegal expansion of housing into the forest. Such a forest fire is expected to have tremendous effects on soil erosion rates, flooding of lowland, degradation of natural vegetation, and land desertification.

The extent of urban area has been expressed in % or ha of soil sealed by built-up structures within agricultural and/or semi-natural land cover units over the studied territory (urban area/total study area). It has defined by using ortho-photomaps or remote sensing image analysis. The following classes have been identified: (a) extent <2%, (b) extent=2-5%, (c) extent=5-10%, (d) extent=10-20% and extent >20%.

The rate of change of urban area is expressed as the area covered over certain time. Its approach is to compare and combine mapping methods based on field surveys and remote sensing image analysis for an efficient geo-referenced identification and quantification of the extent of dispersed built-up structures within semi-natural/agricultural areas expressed in ha/10 years/10 km^2 of territory. The following 4 classes of change of urban areas have been defined: (a) very low (<5 ha/10 years/10 km^2 of territory), (b) low (5-10 ha/10 years/10 km^2 of territory), (c) moderate (10-20 ha10 years/10 km^2 of territory), and (d) high (>20 ha10 years/10 km^2 of territory).

As Table 11 shows, data for these indicators were collected only in 9 study field sites corresponding to Boteti Area-Botswana. The urban area for this study site covers less than 2% of the territory, while the rate of expansion is estimated to less than 5 ha/10 years/10 km^2 of territory.

Distance of low elevation lands from the sea shore

This indicator is mainly used to assess the effect of water quality on soil salinization risk. The shorter the distance of a site from the nearby seashore, the greater the risk of soil salinization is expected. Soil texture and hydromorphic conditions are greatly related to the distance from the seashore and of course the location in relation to riverbed. Soils located in a short distance and far from the riverbed are usually fine-textured and poorly drained with a permanent ground water table fluctuating between 30-150 cm from the soil surface. Such soils under semi-arid and arid climatic conditions are vulnerable to salininzation and desertification. On the contrary, soils located far from the coast and from the riverbed are usually well drained or some what poorly drained of medium to moderately fine texture. Such soils are lees vulnerable too salinization and desertification under the same climatic conditions (Fig 86).

Fig. 86. Examples of soils located in the same alluvial plain but in different distance from the seashore (left photo-very poorly, fine-textured soil, highly affected from salinization, located

750 m from the seashore; right photo-well drained, moderately fine textured soil, free of salts, located 4200 m from the seashore

The distance form the shortest seashore of study field sites in which the main process of desertification was soil salinization has been measured using topographic maps, aerial photos, etc. The following classes of distance from seashore (D) have been distinguished: (a) D<0.25 km, (b) D=0.25-1 km, (c) D=1-2 km, (d) D=2-5 km, (e) D=5-8 km, (f) D=8-15 km and (g) D>15 km.

Data for this indicator were collected in 258 study field sites, corresponding to 5 study sites. The dominant class of distance from the seashore was greater than 15 km, covering 45% of the study field sites. Such field sites have been located in all cases of the study sites of Boteti Area-Botswana, Djanybek-Russia, and Novij Saratov-Russia (Fig. 87). The next important class of distance from the seashore was 2-5 km, covering 15.5% of the study field sites and corresponding to the study sites of Nestos Basin Maggana-Greece, and Crete-Greece. The other classes of distance from the seashore shows an almost uniform distribution with frequency of appearance less than 10%, covering all the distances form the seashore (Fig. 87).

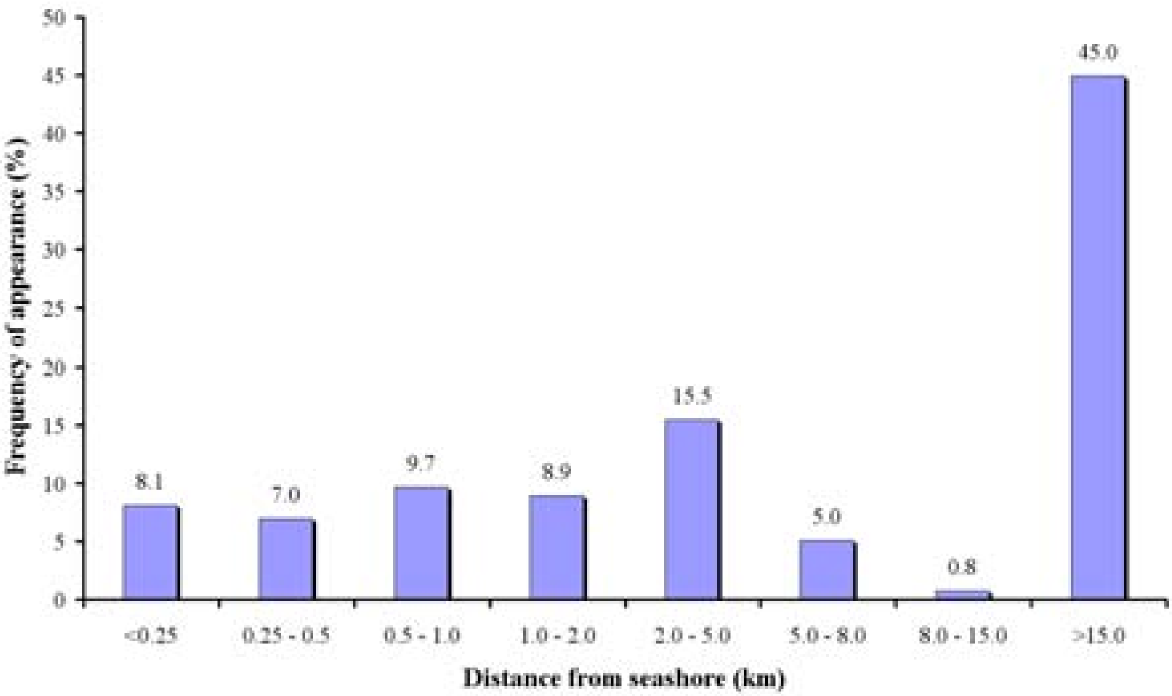

Fig. 87. Distribution distance from seashore classes of the study field sites related to soil salinization

2.12 Water use indicators

Water is a renewable limited resource, which is essential for combating drought and desertification. The key point of sustainable development is to safeguard water resources and to ensure that the availability for public water supplies is provided in such a way that the protection of the environment is achieved. The indicators related to water use provides information on the efficient allocation of water among uses and tools for managing risk associated with drought. The uncontrolled use of water resources in the last decades for both irrigation and domestic consumption resulted in severe environmental impact on the water quality of the most productive aquifers and on soil degradation due to salinization. As it is expected, the areas facing water shortages and overexploitation problems

are those located in semi-arid and arid climatic conditions having high population density, and intensive agriculture activities. The following indicators related to water use have been considered in this project:
(a) Irrigation percentage of arable land, (b) runoff water storage, (c) water consumption per sector, and (d) water scarcity.

Irrigation percentage of arable land

This indicator defines the land area under irrigation as a percentage of total arable land. In addition irrigation percentage of arable land defines the extent in which arable land and water resources are intensively used. Areas with adequate amount of good quality of water available for irrigation are subjected to lower desertification risk. Because the expected warmer and drier climate accompanied with increase in aridity and drought hazard, the extension of irrigation will be necessary over large areas for efficient agricultural production and protection of the environment. The expansion of irrigated land will probably aggravate the existing problem of brackish water intrusion in aquifers through diminishing groundwater recharge or reduced amount of rainfall. The sustainable use of water resources and the appropriate land management systems and land management practices will be the appropriate tools for combating desertification in those areas. The following classes of irrigation percentage of arable land (IP) have been distinguished in this project: (a) very low, IP<5% of the total area is irrigated; (b) low, IP=5-10% of the total area is irrigated; (c) moderate, IP=10-25% of the total area is irrigated; (d) high, IP=25-50% of the total area is irrigated; and (e) very high,IP >50% of the total area is irrigated.


Fig. 88. Non-irrigated land under moderate desertification risks (left) and irrigated land with good quality of water under low desertification risk (right)

As Table 12 shows, irrigation percentage of arable land has been defined in 1169 field sites, corresponding to 12 study sites. The analysis of the data shows that 65.4% of the study field sites are located in areas in which less than 5% of the surrounding land is irrigated (Fig. 89). Such field sites have been found in all cases of the study sites of Boteti Area-Botswana, Secano Interior-Chile, Guadalentin Basin Murcia-Spain, Mamora Sehoul-Morocco, and Djanybek-Russia, and in some cases in the study sites of Cointzio Catchment-Mexico, Novij Saratov-Russia, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, and Crete-Greece. The next important class of irrigation was >50% of the total arable land irrigated, covering 18.5% of the total study field sites. Such field sites have been found in the study sites of Novij Saratov-Russia, Nestos Basin Maggana-Greece, Santiago Island-Cape Verde, and Crete-Greece. Percentage irrigated arable land in the class 25-50% has been defined in 9.5% of the study sites, corresponding to the study sites of Crete-Greece. The class 5-10% of the arable irrigated has been defined in 6.0% of the study field sites, corresponding to study sites of Novij Saratov-Russia, Zeuss Koutine-Tunisia, and Santiago Island-Cape Verde.

Table 12**. Number of field sites in which indicators related to water use was recorded in the filled questionnaires**

site no	Study site	Number of field sites described for the indicator			
		Irrigation percentage of arable land	Runoff Water Storage	Water Consumption by Sector	Water Scarcity
1	Rendina Basin, Basilicata, Italy	-	-	-	-
2	Loess Plateau, China	-	-	-	-
3	Mação, Portugal	-	-	-	31
4	Secano Interior, Chile	28	28	-	-
5	Nestos Basin, Maggana, Greece	30	-	-	30
6	Konya, Karapinar plain, Turkey	-	74	-	74
7	Boteti Area, Botswana	21	45	12	49
8	Zeuss-Koutine, Tunisia	120	118	-	-
9	Mamora/Sehoul, Morocco	120	120	-	-
10	Eskisehir, Turkey	70	70	-	70
11	Santiago Island, Cape Verde	103	103	-	-
12	Guadalentin Basin, Murcia, Spain	121	121	-	-
13	Djanybek, Russia	98	69	29	138
14	Novij, Saratov, Russia	122	84	62	100
15	Crete, Greece	269	155	-	114
16	Cointzio Watershed, Mexico	67	67	-	20
17	Gois, Portugal	-	-	-	30
	TOTAL	1169	1054	103	656

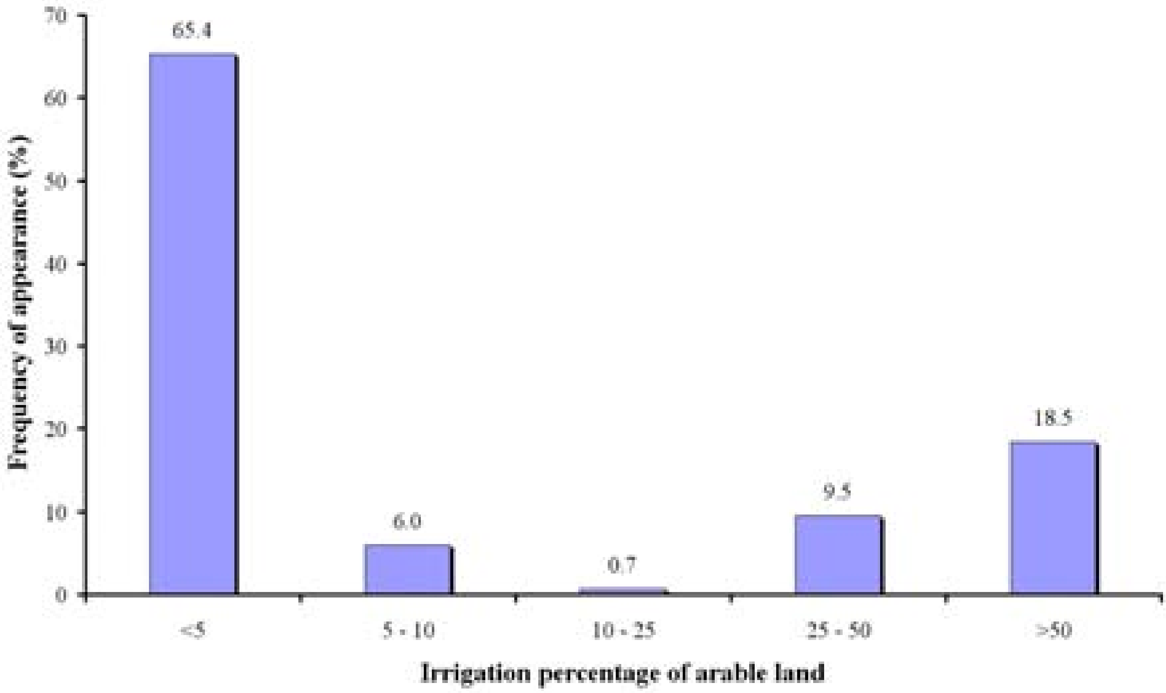

Fig. 89. Distribution of irrigation percentage classes of arable land defined in the study field sites

Runoff water storage

Surface water Runoff is the most important direct driver of soil erosion in hilly areas. There are many factors and processes affecting water runoff such as vegetation density, biological activity, soil crusting, micro-topography, soil texture and structure, plant cover, rainfall amount and intensity, slope gradient land management practices, etc. The degree of crusting of soil surface has a strong influence on infiltration rates and therefore surface water runoff rates. Micro-topography of the soil surface consisting of random roughness on the surface, together with cultivation features such as plough ridges retards water flow and increases amount of water infiltrating into the soil.

Runoff water storage is defined as the volume of runoff water stored into the soil or in small ponds. Storage of water runoff is defined in terms of land management for reducing surface water runoff and increasing soil infiltration rates. For example, presence of adequate shrubby or annual vegetation cover, high biological activity, construction of terraces, shallow ploughing of the soil parallel to the contour lines, concentrating the runoff water in small ponds and retarding runoff, keeping plant residues on the soil surface, etc. are some practices for runoff water storage (Fig. 90a). Measurement of the indicator is based on self-assessment subject to personal judgement if existing management practices for runoff water storage are applied, and how efficient they are for the study field site. The following classes have been distinguished: (a) no actions for runoff water storage, (b) low actions for runoff water storage, (c) moderate actions for runoff water storage, and (d) adequate actions for runoff water storage.

 

Fig. 90a. Typical examples of surface water runoff storage small ponds constructed around the tree and concentrating the nearby the tree runoff (left) or on a water way storing runoff from larger area (right)

Data for this indicator have been defined for 1054 study sites, corresponding to 12 study sites (Table 12). As Fig 90b shows, no runoff water storage actions have been identified in the majority of the study field sites, covering 61.8% of the total field sites. Such land management practices has been found in all study field sites of Novij Saratov-Russia, Djanybek-Russia, Guadalentin Basin Murcia-Spain, Eskisehir-Turkey, and Konya Karapinar plain-Turkey sites, and in some field sites of Boteti Area-Botswana, Djanybek-Russia, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico, and Crete-Greece. Low actions of surface water runoff storage was the next important class, covering 18.1% of the study field sites, and corresponding to few cases in the study sites of Boteti Area-Botswana, Djanybek-Russia, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Cointzio Catchment-Mexico, and Crete-Greece. Adequate actions of surface water runoff storage have been defined in 9.9% of the study field sites, corresponding to some cases of the study sites of Boteti Area-Botswana, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece. Finally, moderate actions of surface water runoff storage has been identified in 10.2% of the study field sites, corresponding to few cases in the study field sites of Boteti Area-Botswana, Cointzio Catchment-Mexico, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece.

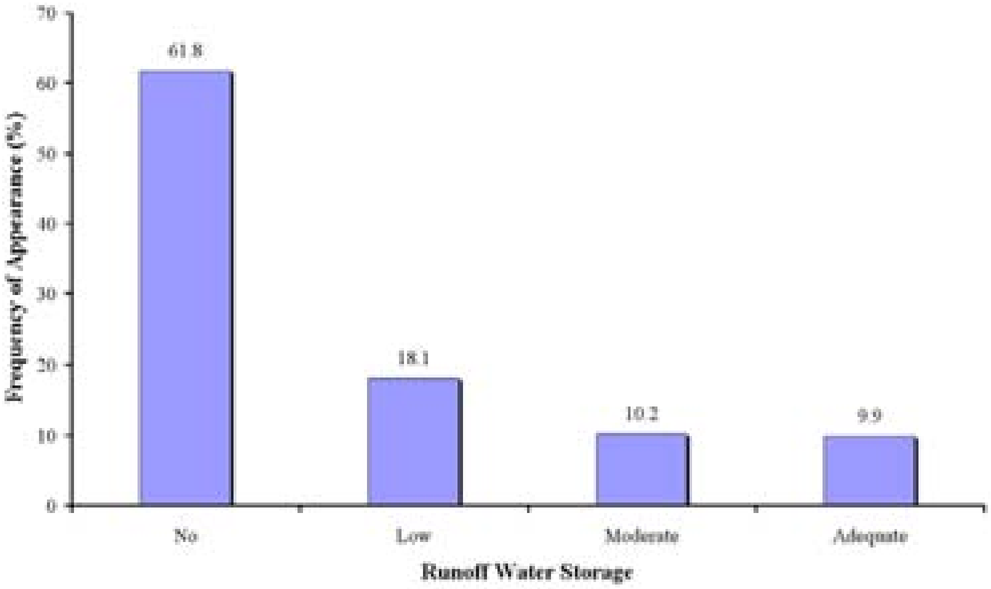

Fig. 90b. Distribution of runoff water storage classes defined in the study field sites

Water consumption per sector

Water consumption per sector is defined as the annual water consumption for domestic use, industrial use, agricultural use and other sectors expressed in cubic metres per year or as a percentage of total water consumption. These indicators can be used for water resources management by identifying crucial sectors of consumption in which specific future plans have to be developed. Usually, the given hierarchy among the various sectors of water consumption is domestic, industrial, agriculture. Therefore, the amount of water consumption for agriculture becomes a crucial factor for desertification vulnerability of areas facing water scarcity problems. The calculation of the percentage for each sector has been defined by dividing the consumption of each sector by the total water consumption. The data for this indicator have been collected from the local administration or the national statistical services.

As Table 12 shows, data for this indicator have been defined in 103 study field sites, corresponding to 3 study sites of Boteti Area-Botswana, Novij Saratov-Russia, and Djanybek-Russia. The analysis of the data showed that the main consumer of water is agriculture corresponding to 61.2% of the sites, while in 36.9% of the field sites domestic is the main sector of water consumption.

Water scarcity

This indicator assesses the change in the difference between the water availability per capita and the water consumption per capita during the past 10 years. The change in water scarcity can be affected both on the increased consumption and/or decrease in supply. Scarcity, by definition means diminishing resources (for example due to climate change) and/or a pressure on the supply of available resources from an increasing demand (Fig. 91). The water consumption per capita includes the total demands for drinking water, process water, irrigation water and cooling water by all economic sectors, expressed in cubic metres per year per capita. The World Health Organization uses the level of 1,000-2,000 cubic meters per person per year to identify risk on water scarcity. When these values drop below 1,000 cubic meters per person per year, then areas are considered as experiencing water scarcity.

Fig. 91. Water resources used for human consumption (left) but under dry climatic conditions and disappearing of surface water then water (right) scarcity becomes a major issue

This indicator has been defined for this project as the ratio of water availability per capita (WAC) divided by the water consumption per capita (WCC) per year for the period of the past ten years. The following 5 classes have been identified: (a) no water scarcity, WAC/WCC=R>2; (b) low, R=1.5-2; (c) moderate, R=1.5-1.0; (d) high, R=0.5-1.0, and (e) very high R<0.5.

As Table 12 shows, data for this indicator were defined for 656 study field sites, corresponding to 10 study sites. The analysis of the data showed that the main class of water scarcity is high, covering 54.3% of the study sites, and corresponding to all field sites of Djanybek-Russia, Eskisehir-Turkey, and Konya Karapinar plain-Turkey, and in some cases in the study sites of Boteti Area-Botswana, Cointzio Catchment-Mexico, and Crete-Greece (Fig. 92). The next important class of water scarcity is low, covering 19.5% of the study field sites, corresponding to all study field sites of Novij Saratov-Russia, and is some cases in the study sites of Boteti Area-Botswana, Cointzio Catchment-Mexico, and Crete-Greece. Moderate water scarcity class has been defined in 13.6% of the study field sites, corresponding to some cases of the study sites of Boteti Area-Botswana, Nestos Basin Maggana-Greece, Cointzio Catchment-Mexico, and Crete-Greece. No water scarcity has been defined in 9.5% of the study sites, corresponding to Mação- Portugal, and Gois-Portugal study sites. Finally, very high water scarcity has been defined in the study field sites of Mação-Portugal site since the study sites are exclusively located in forested areas.

2.13 Indicators related to tourism

The Mediterranean coastline is roughly 46,000 km long and is almost equally divided into rocky and sedimentary coasts. Over the last three decades the Mediterranean countries experienced a tremendous growth of population increase. Population pressure is exacerbated by tourism. Tourism industry plays an important role in the Mediterranean economy and it is expected to increase in the near future. However, tourism has created a number of environmental problems ranging from loss of agriculture lands, water pollution, coastal erosion, increasing water consumption, decreasing recharge of aquifers, flooding of lowland, soil salinization, etc. The increasing tourism exerts a significant impact on the land-use patterns and the allocation of water resources. The most immediate changes in land-use is: (a) the shift in crop production to meet the high tourist requirements, (b) the replacing several of the traditional crops, and (c) the abandonment of lands of low quality. The high demands for water consumption or other economic activities have increased the price of water and forcing the cost of agricultural production, while in many cases, water of low quality is used for irrigation causing soil salinization problems. Coastlines are being sealed over by harbours and marinas, roads, houses, other facilities to accommodate the expansion of tourist industry, removing fertile soils from production and the interrupting functions with the environment.

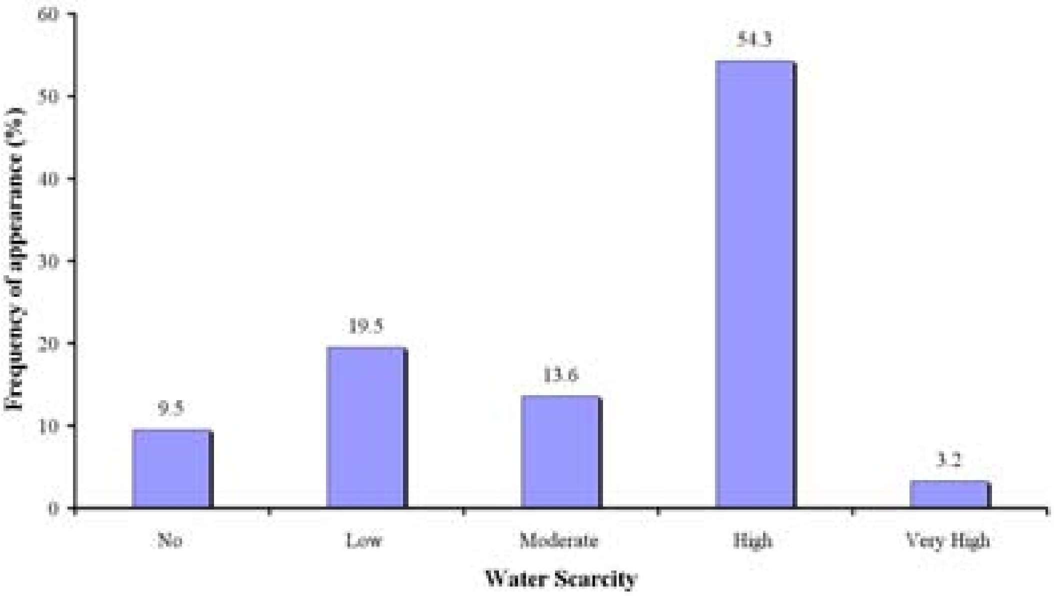

Fig. 92. Distribution of water scarcity classes identified in the study field sites

Some of the study sites located in the inland; such as Djanybek-Russia, Guadalentin Basin Murcia-Spain, Eskisehir-Turkey; do not have significant effects from tourism, but others such as Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Konya Karapinar plain-Turkey, Crete-Greece are subjected to high tourism pressure (Fig. 93). The following two indicators have been selected for assessing the effect of tourism on land degradation and desertification: (a) tourism intensity, and (b) tourism change.

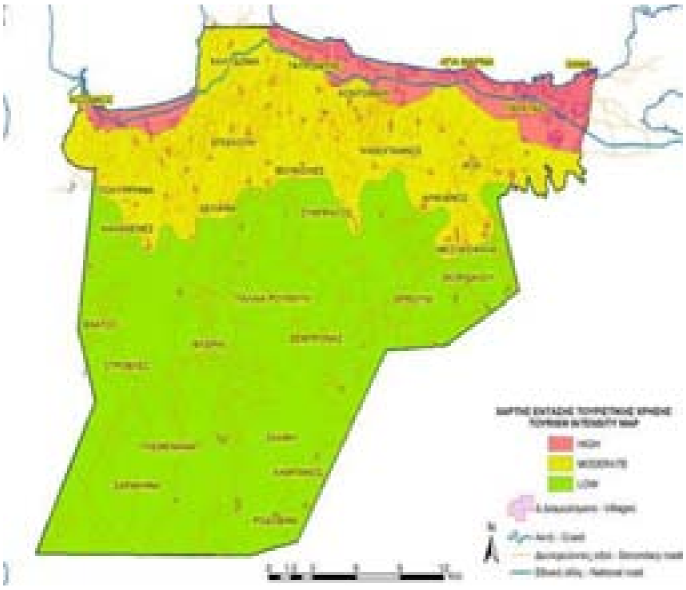

Fig. 93. Map of region of Chania-Crete showing areas subjected to high (red color), moderate (yellow color) and low (green color) tourism pressure

<u>Tourism intensity</u>

This indicator shows the average distribution of tourists and gives a general indication of pressures on natural resources, with regard to a reference period (year) or during a peak season. The Mediterranean region is the third most preferred international tourist destination and the first for European tourists, accommodating around 218 million visitors every year. According to the World Tourism Organization tourists' movement in the Mediterranean would increase in the near future. It is estimated than by the year 2025 the region would receive 396 million international and 273 million domestic tourists.

Tourism intensity is defined as the number of overnights stays by tourists per 10 square kilometres per annum and in peak season. It is a regional indicator covering broad areas. It has been calculated for the study sites by dividing the number of overnight stays (including second homes) with regard to a reference period (year) or within a peak season by the area of 10 square kilometres. The following classes have been defined for this project: (a) low, number of overnight stays / 10 km^2 areas = R <0.01; (b) moderate, R=0.01-0.04, (c) high, R=0.04-0.08; and (d) very high, R>0.08.

Data for this indicator were defined for 1342 field sites, corresponding to 15 study sites (Table 13). As Fig. 93 shows, the prevailing tourist intensity is low, covering 80.8% of the study field site. Such tourism intensity has been found in all study field sites of the study sites of Djanybek-Russia, Secano Interior-Chile, Nestos Basin Maggana-Greece, Eskisehir-Turkey, Guadalentin Basin Murcia-Spain, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, Gois-Portugal, and Mação- Portugal, and is some areas of the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Eskisehir-Turkey, and Crete-Greece. The next important class of tourism intensity is moderate, covering 14.2% of the study field sites, and corresponding to the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Santiago Island-Cape Verde, Zeuss Koutine-Tunisia, Konya Karapinar plain-Turkey, Cointzio Catchment-

Mexico, and Crete-Greece. High tourism intensity has been identified in 4.9% of the study sites, corresponding to few cases of the Crete-Greece study site (Fig. 93).

Table 13. Number of field sites in which indicators related to tourism was recorded in the filled questionnaires

site no	Study site	Number of field sites described for the indicator	
		Tourism intensity (Number of overnight stays / 10 km^2 area)	**Tourism change** (Number of overnight stays in a specific destination over one year / average overnight stays in the last 10 years)
1	**Rendina Basin, Basilicata, Italy**	**-**	**-**
2	**Loess Plateau, China**	**-**	**-**
3	**Secano Interior, Chile**	**28**	**-**
4	**Nestos Basin, Maggana, Greece**	**30**	**-**
5	**Gois, Portugal**	**30**	**30**
6	**Mação, Portugal**	**31**	**31**
7	**Boteti Area, Botswana**	**39**	**25**
8	**Eskisehir, Turkey**	**70**	**-**
9	**Konya, Karapinar plain, Turkey**	**74**	**-**
10	**Santiago Island, Cape Verde**	**103**	**-**
11	**Cointzio Watershed, Mexico**	**87**	**20**
12	**Mamora/Sehoul, Morocco**	**120**	**-**
13	**Zeuss-Koutine, Tunisia**	**120**	**-**
14	**Guadalentin Basin, Murcia, Spain**	**121**	**-**
15	**Djanybek, Russia**	**98**	**29**
16	**Novij, Saratov, Russia**	**122**	**62**
17	**Crete, Greece**	**269**	**-**
	TOTAL	**1342**	**197**

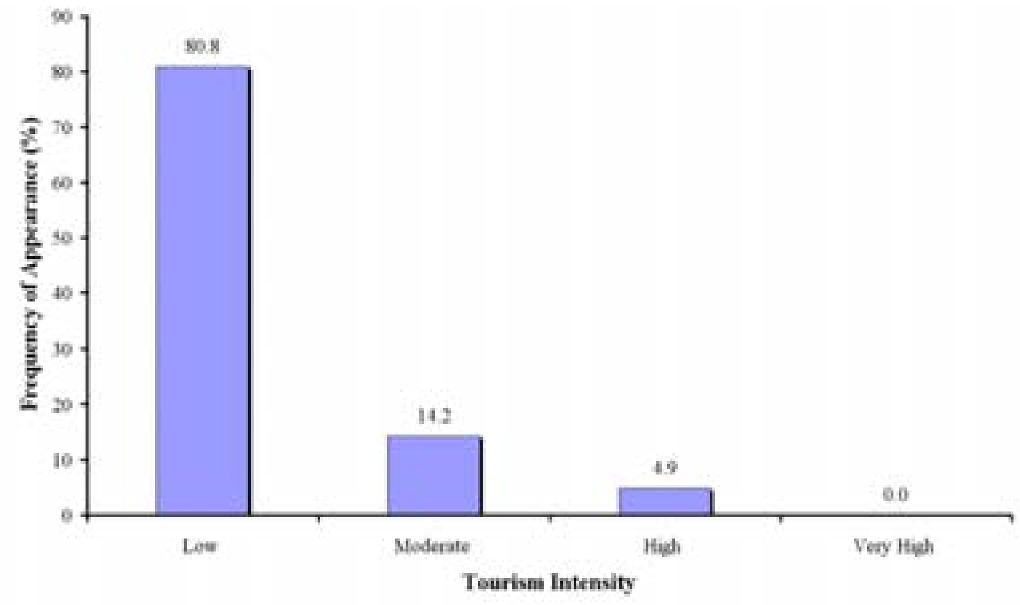

Fig. 93. Distribution of tourism intensity classes defined in the study field sites

Tourism change

This indicator assesses how the tourism destinations have changed in the last 10 years in a specific area. It is calculated by comparing the number of overnight stays (including second homes) in a specific destination over one year by the average number of tourists overnight stays in the last 10 years. The following classes have been defined for this project: (a) low- number of overnight stays in a specific destination over one year / average overnight stays in the last 10 years=R<1 (expressed %), (b) moderate-R=2-5%, (c) high-R=5-10%, and (d) very high-R>10%. Data for this indicator have been provided from the National Statistical Service.

As Table 13 shows, data for this indicator have been defined for 197 field sites corresponding to the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Djanybek-Russia, Gois, Portugal, Cointzio Watershed, Mexico, and Mação- Portugal. The analysis of the data showed that 93.9% of the study field sites have been considered as subjected to low tourism change in the last decade.

2.14 Indicators related to human characteristics

The use of social, economic and environmental indicators at several levels (national, regional and local) has become a common assessment tool for land degradation. Changes in the social structure of an area can be both a driving force and an impact on land degradation and desertification. Changes in the social structure can occur under the local socio-economic conditions has become incapable for satisfying the population's needs. This may be the result of land degradation caused in the landscape in the previous time resulting in decreasing land productivity and farmers' income. Under such conditions, land is abandoned and population migrates to other more promising areas. But the concentration of people in certain areas results in large pressure on the land resources and especially on water resources due to continuously increasing demands for food and water consumption. The increasing demands for food and water results on intensive use of natural resources and a new cycle of land degradation and desertification is initiated in the areas of high population density.

The following indicators have been selected related to social characteristics of the study sites for the purposes of the DESIRE project: (a) human poverty index, (b) old age index, (c) population density, (d) population growth rate, and (e) population distribution. Most of indicators are classified as regional indicators and are referred in broad areas or in the whole study site.

Human poverty index

As it is defined by the UNDP (United Nations Development Programme), Human Poverty Index is a compound index, based on a number of component measures that calculates a summary statistic on the economic welfare of the poor in a society. Since poverty is a multidimensional issue and a relative concept, therefore different factors and different expectations need to be taken into account in different countries. The HPI-2 indices developed by the UNDP have been used for the DESIRE project. HPI-2 has been based on four component measures of deprivation, each of which need to be defined:

- Longevity: the percentage of the population with a life expectancy of less than 60 years.
- Illiteracy: the percentage of the population aged 15 years or over who are unable, with understanding, both to read and write a short, simple statement on their everyday life.
- Standard of living: the percentage of the population living below the poverty line (defined as 50% of the median disposable personal income).
- Exclusion: percentage of the work force in long-term unemployment (12 months or more).

These four components have been computed using the following equation:

$$\textbf{HPI-2} = [0.25(P2^3+P4^3+P5^3+P6^3)]^{0.33}$$

Where: P2 = illiteracy rate for the people aged 15 years of older
P4 = percentage of people not expected to survive more that 60 years
P5 = percentage of people with disposable income < 50% of the median income
P6 = percentage of people in long term unemployment.

The following classes have been defined: (a) low- HPI-2 <10, (b) moderate- HPI-2 = 10-20, (c) high- HPI-2 = 20-50, and (d) very high- HPI-2 >50. The necessary data for calculating poverty index have been collected from the National Statistical Service of the study sites.

As Table 14 shows, data for this indicator have been collected for 217 field sites, corresponding to 5 study sites. The analysis of the data have shown moderate is the dominant class of human poverty index, covering 50.2% of the study field sites (Fig. 94). Such class of poverty index has been defined for all study field sites of Djanybek-Russia, Gois-Portugal, and Konya Karapinar plain-Turkey study sites. Low human poverty index is the next important class, covering 41.9% of the study field sites, and corresponding to all field sites of Novij Saratov-Russia, Cointzio Catchment-Mexico, and Mação-Portugal. High poverty index has been defined in 7.5% of the study field sites, corresponding to the some of the field sites of Boteti Area-Botswana. Finally, in few field sites of Boteti have been described as subjected to very high human poverty index (Fig. 94).

Table 14. Number of field sites in which indicators related to social characteristics was defined in the filled questionnaires

	Study site	Number of field sites described for the indicator				
		Human poverty index	Old age index	Population density	Population growth rate	Population distribution
1	Rendina Basin, Basilicata, Italy	-	-	-	-	-
2	Loess Plateau, China	-	-	-	-	-
3	Nestos Basin, Maggana, Greece	-	-	30	-	-
4	Gois, Portugal	-	-	30	-	-
5	Mação, Portugal	31	-	31	-	-
6	Secano Interior, Chile	-	28	28	28	-
7	Boteti Area, Botswana	21	45	65	54	9
8	Eskisehir, Turkey	-	70	70	70	-
9	Cointzio Watershed, Mexico	-	67	87	67	-
10	Konya, Karapinar plain, Turkey	74	74	74	74	-
11	Djanybek, Russia	29	69	138	69	-
12	Santiago Island, Cape Verde	-	103	103	103	-
13	Novij, Saratov, Russia	62	84	122	84	-
14	Mamora/Sehoul, Morocco	-	120	120	120	-
15	Zeuss-Koutine, Tunisia	-	120	120	120	-
16	Guadalentin Basin, Murcia, Spain	-	121	121	121	-
17	Crete, Greece	-	155	269	155	9
	TOTAL	217	1056	1408	1065	18

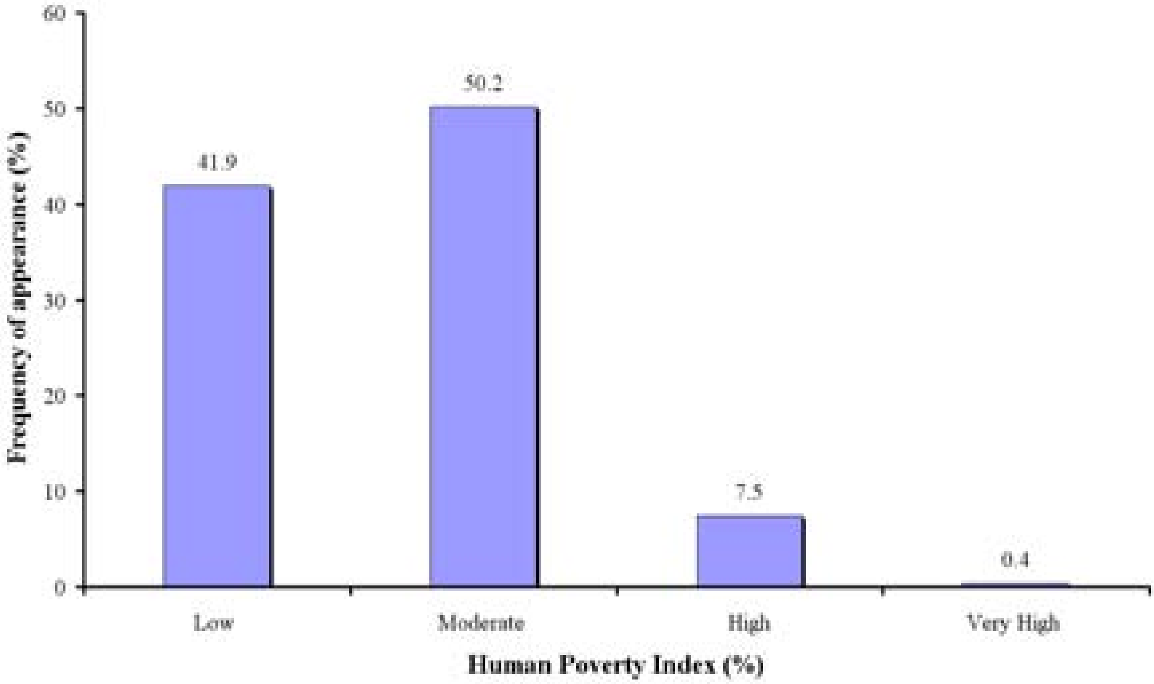

Fig. 94. Distribution of human poverty index classes defined in the study field sites

Old age index

The old age index measures the relationship between the populations over the age of 65 divided by the total population. The purpose of the indicator is to emphasize the strong imbalance that exists between the large numbers of elderly people in relations to the total population. This index is related to the applied land management practices and to the introduction of new technologies. Elder people used to remain under the traditional land management practices, while younger farmers are relatively easily convinced to introduce new technologies and land management practices, considering sustainability of land resources. Furthermore, elder people in dry lands are not usually replaced in farming by their sons and the land is often abandoned or land management practice or land use changes leading later to abandonment after possible further degradation.

The old age index (R) has been calculated by the following equation:

$$\text{Old Age Index} = \frac{\text{Population 65 years old and older}}{\text{Total Population}} \times 100$$

Data for calculation of this indicator have been collected from the National Statistical Service of the corresponding study sites. The following classes of old age index have been distinguished for this project: (a) low- old age index R<5, (b) moderate- R=5-10, (c) high- R=10-20, and (d) very high- R>20.

Data for this indicator have been defined in 1056 study field sites, corresponding to 10 study sites (Table 14). As Fig. 95 shows, the old age index is mainly characterized as high, covering 42.9% of the study field sites. Such index has been identified in all cases of the study sites of Guadalentin Basin Murcia-Spain, Eskisehir-Turkey, Konya Karapinar plain-Turkey, and Crete-Greece, and in some cases in the study sites of Boteti Area-Botswana, and Santiago Island-Cape Verde. Moderate was the next important class of old age index, covering 25.2% of the study field sites, and corresponding to the study sites of Djanybek-Russia, Cointzio Catchment-Mexico, Santiago Island-

Cape Verde, and Zeuss Koutine-Tunisia. Low old age index has been defined in 23.4% of the study field sites, corresponding to the study sites of Boteti Area-Botswana, Novij Saratov-Russia, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, and Zeuss Koutine-Tunisia. Finally, very high old age index has been identified in 8.5% of the study field sites, corresponding to Novij Saratov-Russia, Secano Interior-Chile, and Djanybek-Russia study sites.

Population density

Population density is an indicator closely related with the level of human pressure to natural resources and with the sensitivity of an area to land degradation and desertification. Over the last decades the Mediterranean countries have experienced a tremendous increase of population. In 2000 the whole 22 riparian countries had 428 million people compared to 285 million in 1970. The population density is quite different between northern and southern countries with the latest having an annual growth rate of 2.35% per year or an increase of 3.9 million people per year for all the countries from Morocco to Turkey. These numbers are five times higher than the northern Mediterranean countries.

Population density has been defined as the ratio between (total) population and surface (land) area in which this population exists. This ratio has been calculated for the different territorial units in each study site, for any point in time, depending on the source of the population data. An alternative definition for population density is the number of persons per unit of area, which may include or exclude cultivated or potentially productive area. The following equation has been used for calculation of population density (PD) (source: http://en.wikipedia.org/wiki/Population_density):

$$\text{Population Density} = \frac{\text{No of individuals}}{\text{Area of the region in which they live}} = \frac{\text{People}}{\text{km}^2}$$

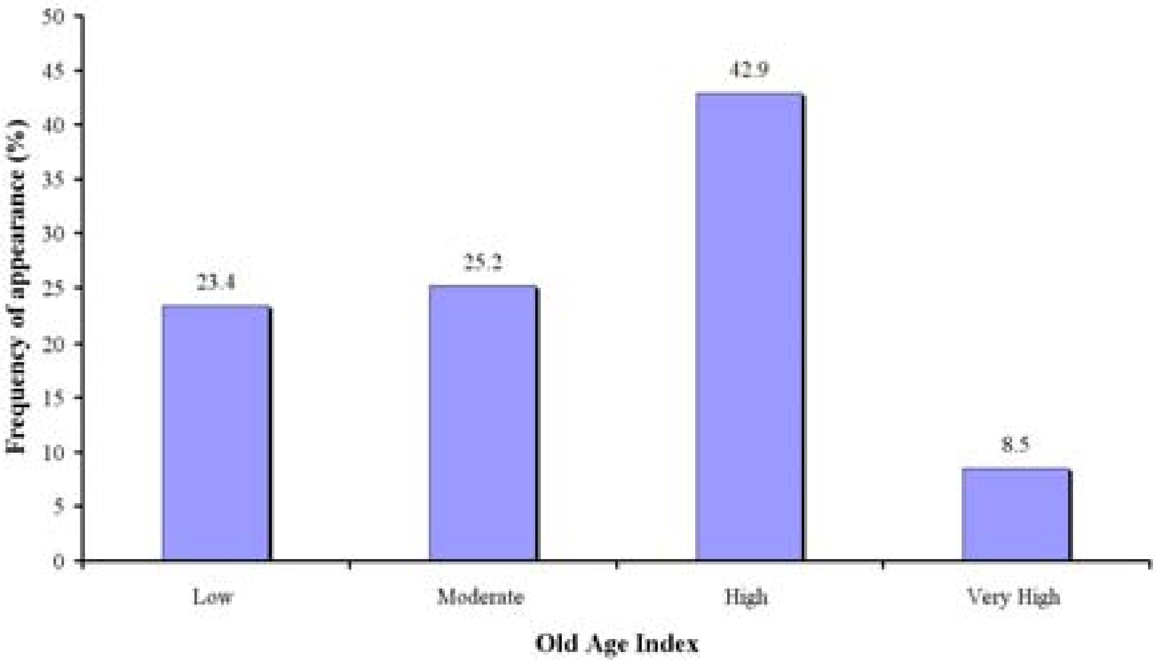

Fig. 95. Distribution of old age index classes defined in the study field sites

The following classes have been defined for this project: (a) low- PD< 50 people/km^2), (b) moderate-PD=50-100 people/km^2), (c) high-PD=100-300 people/km^2, and (d) very high-PD>300 people/ km^2.

As Table 14 shows, this indicator has been defined in 1408 field sites, corresponding to 15 study sites. The analysis of the data have shown low population density is the prevailing class, covering 61.4% of the study field sites (Fig. 96). Such population density has been defined in all cases of the study sites of Boteti Area-Botswana, Gois-Portugal, Djanybek-Russia, Secano Interior-Chile, Guadalentin Basin Murcia-Spain, Zeuss Koutine-Tunisia, Eskisehir-Turkey, Nestos Basin Maggana-Greece, Konya Karapinar plain-Turkey, and Mação- Portugal, and in some field sites of Crete-Greece, Cointzio Catchment-Mexico, and Novij Saratov-Russia. Moderate population density (PD=50-100 people/km^2) has been defined in 32.5% of the study field sites, corresponding to the study sites Novij Saratov-Russia, Santiago Island-Cape Verde, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, and Crete-Greece. High population density (PD=100-300 people/km^2) has been described in 6.1% of the study field sites, corresponding to the study site of Santiago Island-Cape Verde (Fig. 96).

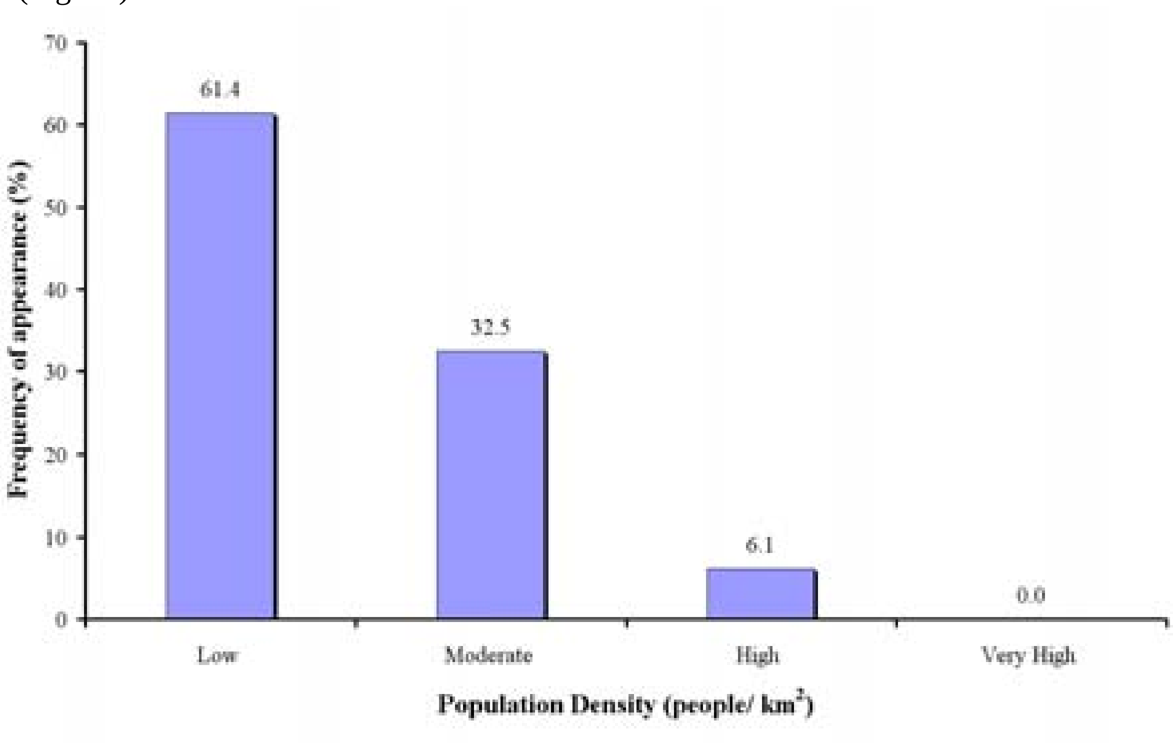

Fig. 96. Distribution of population density classes defined in the study sites

Population growth rate

Population growth rate is a measure of change of population of a certain area. The rate of population growth is identified by Agenda 21 of the United Nations as one of the crucial factors affecting long-term sustainability of natural resources. Rapid population growth can impose limitations on a country's capacity for handling a wide range of economic, social, and environmental issues, particularly when rapid population growth occurs in conection with poverty and lack of access to natural resources.

Population Growth Rate (PGR) has been calculated as the increase in population during a period of time, usually one year, expressed as a percentage of the population at the beginning of the period. It corresponds to the number of births and deaths during the certain period and the number of people migrating to (immigration) and from (emigration) a country. (Source: http://www.worldbank.org/depweb/english/modules/social/pgr). The following equation has been used for calculating population growth rate (PGR) in the study sites:

$$\text{Population Growth Rate} = \frac{(\text{Bith Rate + Immigration}) - (\text{Mortality Rate + Emigration})}{\text{Population Size}}$$

The following classes have been defined for this indicator: (a) low population growth rate- PGR <0.2% per year, (b) moderate- PGR = 0.2-0.4% per year, (c) high- PGR = 0.4-0.6% per year, and (d) very high-PGR>0.6% per year. Data for the above calculation have been taken from the National Statistical Service of the study sites.

Data for this indicator have been defined in 1065 field test, corresponding to 10 study sites (Table 14). As Fig. 96 shows, the dominant class of population growth rate is low (growth rate <0.2% per year), covering 46.0% of the study field sites. Such population growth rate has been defined in the all cases of the study sites of Eskisehir-Turkey, and Konya Karapinar, and in some cases in the study sites of Santiago Island-Cape Verde, Novij Saratov-Russia, Djanybek-Russia, Mamora Sehoul-Morocco, Cointzio Catchment-Mexico, and Zeuss Koutine-Tunisia. Moderate population growth rate has been defined in 29.1% of the study field sites, corresponding to the study sites of Novij Saratov-Russia, Djanybek-Russia, Cointzio Catchment-Mexico, Santiago Island-Cape Verde, Guadalentin Basin Murcia-Spain, and Zeuss Koutine-Tunisia. The next important class of growth rate is high (0.4-0.6% per year), covering 16.0% of the study field sites, and corresponding to the study sites of Santiago Island-Cape Verde, Cointzio Catchment-Mexico, and Crete-Greece. Very high population growth rate has been defined in 8.9% of the study field sites, corresponding to some cases of the study sites of Boteti Area-Botswana, Secano Interior-Chile, and Santiago Island-Cape Verde (Fig. 96).

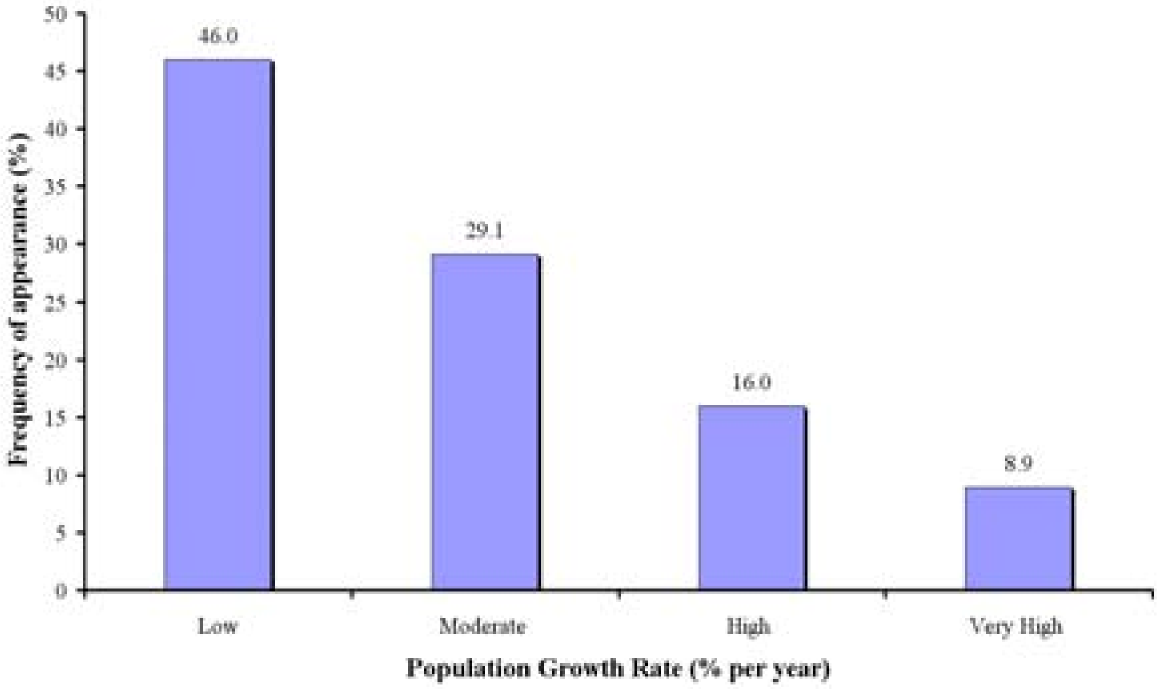

Fig. 96. Distribution of population growth rate classes defined in the study field sites

<u>Population distribution</u>

The population distribution is an indicator related to land management. This indicator classifies an area with two different ways according to: (a) the urbanization of the area, and (b) according to the physical environment. Specifically, the classification of population distribution can be defined as following:

- Urban population / Rural population

- Mountainous population / population in sloping areas / population in lowland

Based on the definitions the classification urban population/rural population (U/R) has been used for the purpose of this project. The following classes of population distribution have been distinguished: (a) U/R>20%, (b) U/R=10-20%, (c) U/R=5-10%, and d) U/R<5%. Data have been collected from the National Statistical Service of the study sites.

As Table 14 shows, data for this indicator have been calculated only for 18 study field sites, corresponding to Nestos Basin Maggana-Greece, and Crete-Greece. The analysis of these data has shown that the urban/rural population rate is less than 5%.

2.15 Institutional indicators

Institutional indicators can be identified as the formal and informal mechanisms including all kinds of policy-relevant societal decision-making processes. The concept of institutional indicators can be considered at different levels, from the micro level of individual decision-making to the macro level of national politics and international regimes (DIS4ME system). The following two functions can be considered as specific for institutional organization to protect land resources: (a) facilitation, at community and individual level, decision-making processes directed towards a more sustainable use of resources; and (b) implementation of political decisions directed to protect land resources. These functions can be improved by local community involvement in the definition of the institutional framework, using a participatory approach that engages stakeholders in identifying priorities and creating programmes and actions to protect land resources. Such priorites can been distinguished in reorganization of the environmental disparity, promotion of sustainable development, and implementation of innovative environmental policies. The following institutional indicators have been defined for the purpose of the DESIRE project: (a) subsidies, (b) protected areas, and (c) policy enforcement of existing regulations.

Subsidies

This indicator aims to assess how the structure of CAP support influences the choice of farmers in terms of agricultural land use and land management practices. However, European Union farm subsidies support has ensured an adequate income to farmers for maintaining landscapes especially in less favoured areas, but this support has favoured the intensification and specialisation process in agriculture by applying more fertilizers, pesticides, irrigating of the land, increasing the number of animals, etc. Under this financial support, unproductive agricultural areas cultivated with cereals, critical to desertification, have remained under cultivation; further deteriorating soil conditions (Fig. 97). Number of animals has increased in unsustainable number causing severe degradation in vegetation and soils (Fig. 97).

Fig. 97. Typical examples of overgrazing (left, Crete) and unproductive agricultural area cultivating with cereals (right, Portugal) highly degraded due to existing policies for subsidy support

Based on the new CAP, additional funds are available as a donation for people who apply measures for protection or improvement of the environment, and/or for improvement of the quality of the agricultural products. The support has been included in the so called “Integrated System”. The system is implemented in the actions such as: compound support, special funding for the quality of the durum wheat, funding for the nutritious seeds, special support for rice, support for cultivation of plants for energy production, funding for the milk production and extra support, special support for cotton, support/1000 m^2 of the traditional olive orchards, production of durum wheat and corn, production of tobacco, production of olive oil and table olives, sugar beet production, beef meat production, sheep and goats feeding, etc.

This indicator have been classified for the purpose of this project in the following categories: (a) no subsidies, (b) subsidies for environmental protection, (c) subsidies for production provided in the basis of area cultivated, number of animals per farmer, amount of production, etc. Data have been collected from the local administration related to institutional characteristics of the study field sites.

As Table 15 shows, data for the indicator “subsidies” have been collected for 1056 study field sites, corresponding to 10 study sites. The analysis of the data have shown that allocation of subsidies for production have been identified in 64.6% of the study sites, corresponding to all field sites of the study sites of Djanybek-Russia, Guadalentin Basin Murcia-Spain, Eskisehir-Turkey, Konya Karapinar plain-Turkey, Cointzio Catchment-Mexico, and Crete-Greece, and in some cases in the study sites of Boteti Area-Botswana, and Zeuss Koutine-Tunisia. No subsidies allocation have been defined in 25.5% of the study field sites, corresponding to all field sites of Novij Saratov-Russia, and Mamora Sehoul-Morocco, and in some field sites of Zeuss Koutine-Tunisia, and Santiago Island-Cape Verde. Subsidies allocated for environmental protection have been identified only in 9.9% of the study field sites, corresponding to the study sites of Zeuss Koutine-Tunisia, Secano Interior-Chile, and Santiago Island-Cape Verde.

Table 15. Number of field sites in which indicators related to institutional characteristics was recorded in the filled questionnaires

Site no	Study site	Number of field sites described for the indicator		
		EU Farm Subsidies	Protected Areas	Policy Enforcement
1	Rendina Basin, Basilicata, Italy	-	-	30
2	Nestos Basin, Maggana, Greece	-	-	30
3	Secano Interior, Chile	28	-	28
4	Gois, Portugal	-	30	30
5	Mação, Portugal	-	31	31
6	Boteti Area, Botswana	45	30	59
7	Loess Plateau, China	-	-	150
8	Cointzio Watershed, Mexico	67	20	87
9	Santiago Island, Cape Verde	103	-	103
10	Novij, Saratov, Russia	84	-	122
11	Eskisehir, Turkey	70	70	70
12	Konya, Karapinar plain, Turkey	74	74	74
13	Mamora/Sehoul, Morocco	120	-	120
14	Zeuss-Koutine, Tunisia	120	-	120

15	**Guadalentin Basin, Murcia, Spain**	**121**	**-**	**121**
16	**Djanybek, Russia**	**69**	**40**	**138**
17	**Crete, Greece**	**155**	**-**	**269**
	TOTAL	**1056**	**295**	**1582**

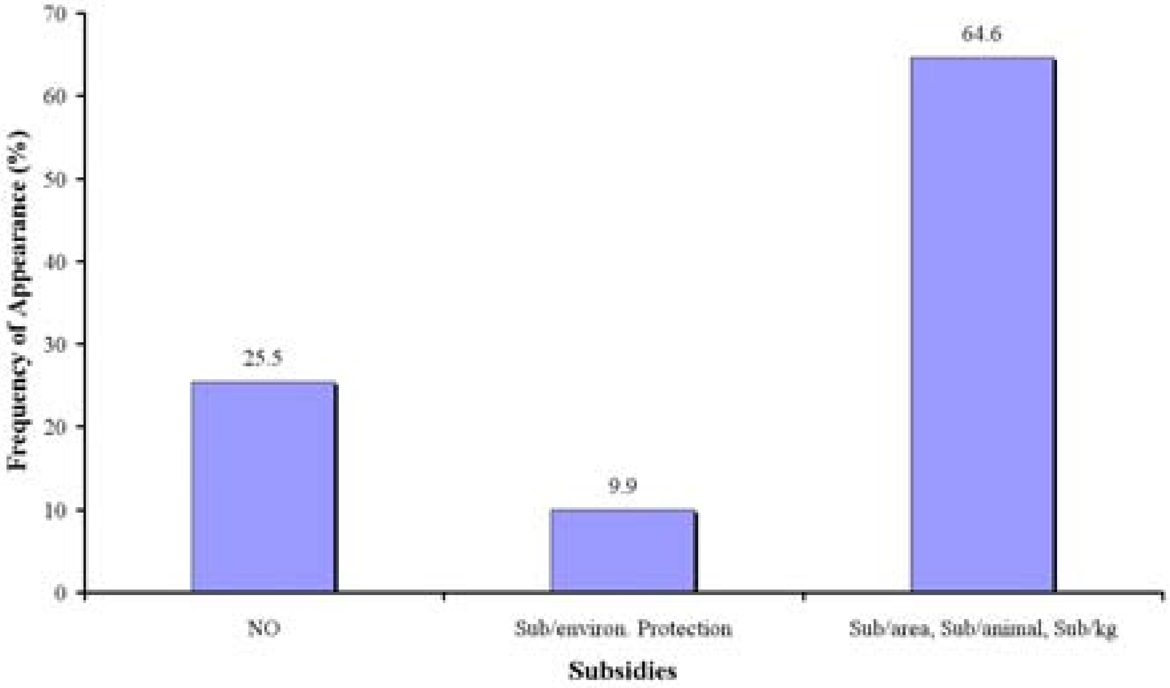

Fig. 97. Distribution of subsidies categories allocated for environmental or production purposes in the study field sites

Protected areas

This indicator includes areas important for conserving biodiversity, cultural heritage, scientific research, recreation, natural resource maintenance, and other values. These areas can be used to identify sustainable management practices to combat desertification. The aim of protected areas is to conserve biological resources, both common and rare, conserving ecosystems and preserving the ecological balance and promoting ecological tourism as part of the diversification of tourism. The World Conservation Union (IUCN) defines the following six management categories of protected areas in two groups: (1) totally protected areas; Category I, Strict Nature Reserves/Wilderness Area (Fig. 96); Category II, National Park; Category III, National Monument; (2) partially protected areas for specific uses such as recreation, or to provide optimum conditions for certain species or ecological communities with Category IV, Habitat/Species Management Area; Category V, Protected Landscape/Seascape; and Category VI, Managed Resource Protected Area (Fig.97). The coastal zone of the Mediterranean region includes many wetlands which play a crucial role in maintaining and enhancing environmental quality and providing valuable economic benefits through their many functions such as water purification, carbon sequestration, maintenance and equilibrium of the water cycle, hosting millions of migratory birds, and providing excellent environments for leisure. There are 81 Ramsar and numerous NATURA 2000 sites in European Union of great importance for protection and conservation of the Mediterranean ecosystems and their cultural heritage.

Fig. 97. Examples of totally protected area (Sanmaria canyon, Crete), and partially protected area (Cape Verde)

This indicator has been defined on the basis of the type of protected area such as: (a) nature reserves/wilderness, (b) national park, (c) national monument, (d) habitat/species management, (e) protected Landscape, and (f) managed resources. The degree of the implementation of existing regulations on environmental protection is assessed in the following indicator "policy enforcement".

As Table 15 shows, data for this indicator were selected in 295 field sites, corresponding to 8 study sites. The majority of the cases where field sites were described (66.8%) have been defined as non-protected areas (Fig. 98). Such field sites have described in the study sites of Boteti Area-Botswana, Gois-Portugal, Djanybek-Russia, Konya Karapinar plain-Turkey, and Mação- Portugal. Nature reserves/wilderness has been defined in 24.4% of the study field sites, corresponding to Eskisehir-Turkey, and Cointzio Catchment-Mexico study sites. Protected landscapes have been identified in 8.8% of the field sites in which this indicator has been described, corresponding in few cases to the study sites of Djanybek-Russia, Konya Karapinar plain-Turkey.

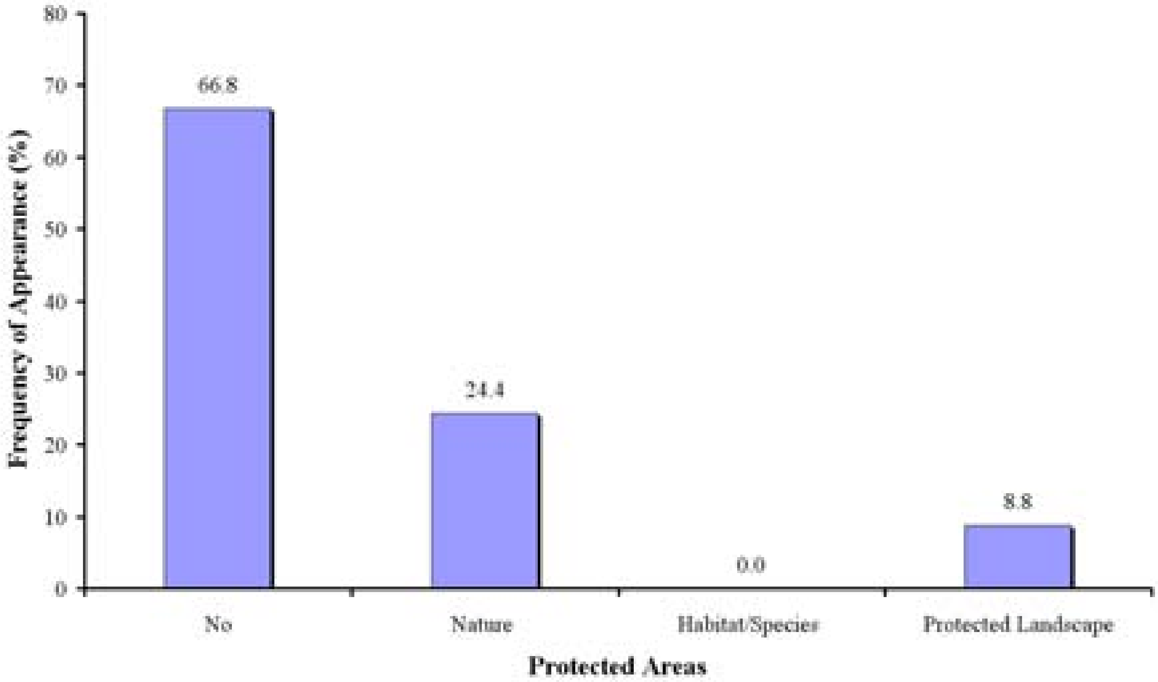

Fig. 98. Distribution of protected areas identified in the study field sites

Policy enforcement

This indicator is related to the enforcement of the implementation of existing regulations on environmental protection. The policy enforcement indicator is used to assess the degree of application of the specific regulation on environmental protection. For example in a cultivated area some typical management practices for reducing tillage and water erosion is: (i) no tillage or minimum tillage, (ii) tillage of soil in the up-slope direction, (iii) contour farming, (iv) enhancement of vegetation cover. Therefore, protection of the land from soil erosion depends on the effectiveness of the implementation /enforcement of such actions (Fig. 98). The information needed depends on the policy under consideration. For example, in the case of terracing protection policy, a relevant piece of information might be the ratio of protected to existing terraces. In the case of extensive agriculture policy, a relevant piece of information might be the percentage of farms (or farmers) or the percentage of area under extensive agriculture.

Fig. 98. Examples of no enforcement of the implementation of existing regulations on environmental protection from soil erosion in grazing land (left) and fully enforcement for protection of olive grove by building terraces (right)

Four classes of policy enforcement have been distinguished in this project: (a) adequate, >75% of the land is protected; (b) moderate, 25-75% of the land is protected; (c) low, <25% of the land is protected; and (d) no protection of the land. The policy enforcement in each field site was assessed by considering the existing regulations for environmental protection in each study site and estimating the degree in which the regulation is applied by personal judgment.

As Table 15 shows, data for this indicator were collected in 1582 field sites, corresponding to 17 study sites. The analysis of data shows that low policy enforcement of existing regulations for environmental protection is the dominant class in the study field sites, covering 39.8% of the field sites. Such conditions have been described in the all field sites of Boteti Area-Botswana, Santiago Island-Cape Verde, Secano Interior-Chile, Guadalentin Basin Murcia-Spain, and Eskisehir-Turkey sites, and in some cases in the study sites of Mamora Sehoul-Morocco, Gois-Portugal, Cointzio Catchment-Mexico, Zeuss Koutine-Tunisia, Loess Plateau-China, and Crete-Greece. The next important class for this indicator is none regulation on environmental protection is implemented, covering 33.3% of the study field sites. Such field sites have been identified in the all cases of the study field sites of Novij Saratov-Russia, Djanybek-Russia, Rendina Basin Basilicata-Italy, and Mação- Portugal sites, and in some cases in the study sites of Loess Plateau-China, Gois-Portugal, Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, and Crete-Greece. Moderate policy enforcement has been identified in 16.1% of the study field sites, corresponding to the study sites of Zeuss Koutine-Tunisia, Konya Karapinar plain-Turkey, Cointzio Catchment-Mexico, Gois-Portugal, and Crete-Greece. Finally, adequate policy enforcement has been identified in 10.9% of the study field sites, corresponding to the study sites of Mamora Sehoul-Morocco, Zeuss Koutine-Tunisia, Loess Plateau-China, Gois-Portugal, and Crete-Greece.

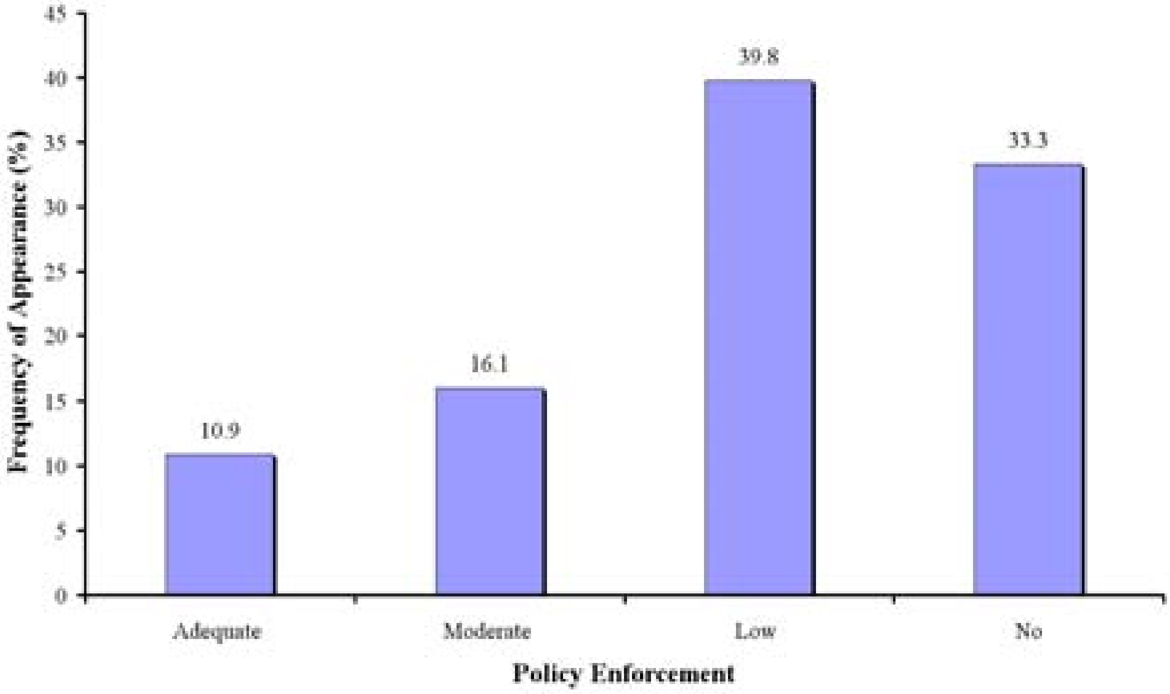

Fig. 99. Distribution of degree of policy enforcement of existing regulations for environmental protection defined in the study field sites

3. Conclusions

A series of 72 indicators related to physical environment, social, economic and institutional characteristics were described in 15 study sites located in Mediterranean and Eastern Europe, Latin America, Africa and Asia. The selected indicators are directly or indirectly related to land degradation and desertification. Questionnaires were prepared and a number of indicators corresponding to specific land degradation process were described in 1641 field sites. The most important process of land degradation identified in the described field sites was soil erosion followed by soil salinization, water stress, forest fires, overgrazing, and urbanization. The number field sites in which each indicator was described varied since each process of land degradation included a group of indicators varied from 30 to 49, and data for some indicators were not available in the various study sites. The defined, indicators were described separately for all study sites using distinct classes. All data have been included on a harmonized data basis on excel form. The collected data from a variety of environmental, social and economic conditions presenting valuable information for areas affected from desertification for deriving tools for assessing the effectiveness of various land management practices and techniques for combating land desertification. After classified the various indicators in categories, a description was carried out separately including all study sites. The main characteristics are summarized as follows.

The climatic conditions of the study sites are mainly characterized as semi-arid with rainfall ranging from 280-650 mm in 72.3% of the study field sites, with high aridity index (BGI>125) in 61.1% of the cases. The seasonality of rainfall is mainly characterized as rather seasonal to mark seasonal in 79.2% of the sites with very low to low erosivity in 82.4% of the study field sites.

The water resources includes mainly water of good quality with low to moderate electrical conductivity in 55.9% of the field sites, while 44.1% of the sites have low water quality for irrigation. The water quantity is characterized as adequate to moderate in 70.4% of the cases. Ground water exploitation has been assessed as without facing problems in 62% of the sites, and the ratio water consumption/water demands was mainly low to moderate in 67.5% of the study filed sites.

The Soils are mainly characterized as well to imperfectly drain in 50.9% of the study field sites, formed mainly on sedimentary and unconsolidated parent materials in 83.6% of the cases, free of rock fragments to moderately stony in 84.2% of the sites. relatively deep to very deep in 51.5% of the sites, moderately fine to fine textured in 56.4% of the sites. Slope gradient greater than 12% has been defined in 57.5% of the cases, with northern slope exposure as dominant class defined in 62.2% of the cases. Soil water storage capacity has been characterized as moderate to high in 51.3% of the cases. Rock outcrops were not present or few in 86% of the study field sites. Soil organic matter content in the soil surface has been identified as low to very low in 77.1% of the sites. Soils were moderately to severely erode in 71.9% of the sites. Finally field sites in which soil salinization was the most important process of land degradation had low to moderate electrical conductivity in 73.2% of the study sites.

The existing vegetation was mainly agricultural crops in 51.4% of the sites while pastures cover 25% of the cases. Vegetation cover types were: cereals (33.2%), olives (18.2%), vines (18.5%), cotton (10.5%), generating vegetation cover less than 50% in 50.9% of the cases. The rate of deforestation was characterized as low in 91.2% of the study field sites.

Water runoff systems has been characterized by fine to very fine drainage density in 57.2% of the study field sites, while flooding frequency in the lowland is rare to no flooding in 60.3% of the cases. The presence of impervious surfaces covered with inert materials was low to moderate in 73.8% of the study areas.

Forest fires have been occurred mainly with low frequency (ecosystem burned every 50-100 years) in 85.5% of the study field sites, even though the fire risk has been characterized as high to very high in 91.4% of the cases. The rate of burned area in the last decade has been defined as low (<10 ha/10 km^2).

The agricultural structure has been characterized as owner-farmed in 64% of the study field sites with variable farm size ranging form 2 to more than 100 ha. Land has been subjected to high fragmentation with more than 7 parcels in 58.5% of the cases. Farmer's income has been assessed as moderate in 70.6% of the study field sites, while farmers are mainly working in the agriculture sector in 60% of the cases.

Cultivation of the land by plowing has been defined in 36.5% of the study field sites while no tillage operations were identified in 35.7% of the cases. The main tillage frequency defined was twice per year in 33.7% of the field sites. Dominant depths of cultivation were less than 20cm and 20-30 cm in 23. % and 26.6% of the cases, respectively. Tillage direction for the fields cultivated was mainly down slope in 37.6% and parallel to the contour lines in 41.6% of the cases. Mechanization index has been characterized as low in 63.5% and moderate in 33% of the study field sites.

Husbandry has been mainly characterized with no grazing control in 50.9% of the field sites, while sustainable grazing has been recorded in 43% of the cases. Grazing intensity has been defined as low in 56.8%, while high has been characterized in 36.2% of the study field sites.

Land management with respect to fire protection has been characterized as low in 62.5% of the study field sites. No sustainable farming has been identified in 53.4%, while no-tillage or minimum tillage has been defined in 33.9% of the cases. No reclamation of affected areas by salts has been identified in 95.3% of the corresponding field sites. No actions for reclamation of miming areas have been defined. No soil erosion control measures have been identified in 73.1% of the cases; while low to moderate measures have been defined in 19.6% of the field sites. No soil water conservation measures have been recorded in 56.3% of the study field sites, while measures such as weed control, mulching have been found in 43.7% of the cases. The study field sites were mainly no terraced in 84. % of the cases.

Land use in relation to the rate of land abandonment has been defined as low (less than 10 ha/10 years/km^2) in 52.8% of the study fields sites, while moderate to high rate of land abandonment (10-50 ha/year/10km^2) has been identified in 45.4% of the cases. Land use intensity in agricultural areas has been characterized as high in 38.5% of the cases, while moderate and low in 29.7% and 31.7% of the field sites, respectively. The period of existing land use was mainly long (more than 25 years) in 70.4% of the study field sites. Urban area and rate of urban area change has been defined low in few of the study sites measured. The field sites studied for soil salinization were located in distance less than 5 km from the seashore in 49.2% of the cases, while the 45% of the fields were in distance greater than 15 km.

The water use for irrigation was mainly limited in less than 5% of the land irrigated in 53% of the fields, while more than 50% of the land irrigated has been defined in 25.4% of the sites. Runoff water storage actions were not defined in 64% of the fields. Water consumption based on the limited number of fields was mainly allocated for agriculture in 61.4% and the rest for other uses. Water scarcity was characterized as high in 42% of the sites while low to moderate in 48.8% of the cases.

Tourism data were available for few study sites in which tourism intensity and tourism change have been characterized as low.

Human characteristics such as poverty index were low in 42.9% of the field sites, while moderate in 47.5% of the cases. Old age index have been characterized mainly as high in 63.9% of the field sites. Population density was basically low in 66% of the cases (less than 50 people/km^2). Population growth rate has been characterized as low (0.2-0.4% per year) in 72.6% of the sites.

Institutional indicators such as subsidies have been mainly allocated for production in 64% of the field sites, while for environmental protection only in 8% of the cases. Protected areas and particularly protected landscapes have been defined only in 14.9% of the study field sites. Finally, policy enforcement of exiting regulations was characterized as low to no enforcement in 72.5% of the study field sites.

Indicators in the terrestrial ecosystem are either of state or of influxes. State indicators are the values of characteristics, which describe the state of its components. In the case of land degradation and desertification, they should be applied to land characteristics describing its principal functions. It is important to know how far or how close are these components to or from describing the state of desertification. State indicators are parameters of soil, vegetation, water and geology. The first three vary with time, where as, the last is rather constant. Influx indicators are parameters of climate, fires, and natural catastrophies and of human interventions, all varying with time. To assess the danger or vulnerability of land to degradation and or to its extreme stage: the desertification, is necessary to accurately define its present state and if possible its past states. Furthermore, land is subjected to influxes that either improve or deteriorate it. The rate of change depends on the intensity of influx indicators, as well as, on the state of land at the particular moment. Therefore, the sensitivity of land to degrading or improving influxes is not a constant but rather an ever changing parameter, requiring a continuous monitoring.

The proposed number of indicators, even though are directly or indirectly related to land degradation, it is too large to be practically applicable. Some of them, easily evaluated, could substitute a number of others. For example vegetation area burned per unit of time, could be used instead of inflammability, management, prevention practices and fire sufficiency extinction methods and facilities. Soil storage capacity could be estimated from soil depth, texture and rockiness. The ratio: of wader demand / available water is powerful indicator of the water regime of an area. Some of the indicators could be estimated from others, and to be easier evaluated, by making use of pedotransfer functions. When crucial indicators, such as soil depth, water scarcity, and destructive human activity reach or surpass critical thresholds, land is heading to desertification, regardless of other favorable state and influx indicators. In some of such cases, human influxes may reverse the course of land decline. However, the respective benefit/cost ratio should be considered.

The effects of the influxes on the state parameters are usually complex and interdependent. They may also have opposite effects depending on the state indicators (e.g. land abandonment, terracing). This makes the accurate scaling and the weighing of the indicators difficult. Scaling the indicators on experience, observations and educated guessing could be useful tool for some practical applications and for comparative evaluations. They should, however, be checked against real situations in the field. The above are some points, which must be considered in evaluating the sensitivity of land to degradation and desertification.

Finally, the above list of indicators will be further analyzed to identify the most appropriate and effective indicators suited to a range of local physical and socio-economic conditions for assessing the effectiveness of the various land management practices in land uses and landscapes prone to desertification.

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