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Land abandonment and slope gradient as key factors of soil erosion in Mediterranean terraced lands

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Abstract

An important land use change recorded in the Mediterranean basin comprises the abandonment of agricultural lands due to economic and social changes, which is followed by significant impacts on soil erosion. Observed land abandonment may have positive or negative impacts on soil protection from erosion because fundamental ecosystem processes are influenced by changes in agricultural practices and soil resources management. Olive groves comprise a typical example of traditional, extensive cultivation, which is abandoned. The olive groves are spread on marginal areas and located mainly on sloping terraced lands with low productivity soils. A field study was conducted for two years in order to monitor the change through time of natural resources such as soil and vegetation, following land abandonment, considering three land uses, cultivation, short-time abandonment and long-time abandonment. Experimental plots were established on two specific slope gradients so that results could be comparable. The study was based on the determination of water erosivity measuring parameters such as rainfall characteristics, sediment losses and water runoff volume, and on the determination of soil erodibility, measuring parameters related to vegetation, soil, slope profile description and drystone terraces. Results show that abandonment of traditional extensive cultivation in the Mediterranean basin has different impacts on soil sediment losses according to slope gradient. When slope gradient is steep (25%), soil erosion is increasing significantly probably because the dense protective cover of annual plants decrease and shrubs' vegetation cover increases. At the same time, bare soil surface below the shrubs' foliage increases as well, while drystone terraces supporting soil material and runoff water collapse. When slope gradient is very steep (40%), soil sediment losses remain at the same high levels after cultivation abandonment because slope gradient is the main factor controlling soil erosion, although soil and vegetation properties are changing.

Keywords: Soil erosion; Mediterranean; Abandonment; Land use change; Slope gradient; Terraces

1. Introduction

One of the most important land use changes recorded in the Mediterranean basin, with particular impacts on soil erosion, is the abandonment of agricultural lands due to economic and social changes. Fundamental ecosystem processes are influenced by changes in agricultural practices and soil resources management, affecting ecosystem functions. Land abandonment in the Mediterranean is noted very often in marginal mountainous or semi-mountainous and difficult to access areas, where agriculture was until recent years traditional or semi-traditional with low inputs and high human labor intensity (Loumou and Giourga, 2002).

Olive tree cultivation is a typical example of traditional extensive cultivation spread on marginal areas. Olive groves are located mainly on sloping terraced lands with low productivity soils, and plantations are aged many decades or even hundreds of years (Beaufoy, 2000). Although abandonment of marginal olive groves is evident and undoubtful, it is very difficult to estimate the exact number of areas abandoned. Calculation by remote sensing methods (Hatzopoulos et al., 1992) is problematic because of natural vegetation regeneration and available statistical data are inaccurate and unreliable because of complicated ownership status, lacking of property titles and a National Cadastre (Kizos and Koulouri, 2005).

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Observed abandonment of agricultural lands may have positive or negative impacts on soil protection from erosion (Kosmas, 1995). In Mediterranean basin and areas with high erosion risk, land abandonment is followed by natural vegetation regeneration resulting in soil erosion decrease (Grove and Rackham, 2001). According to theory as shrub vegetation is increasing, protection of soil resources is also increasing and soil erosion is decreasing (Wischmeier, 1960; Elwell and Stocking, 1976; Morgan, 1986; Francis and Thornes, 1990; Alias et al., 1997). Also, after abandonment, soil properties such as organic matter content, soil structure and infiltration rate are improving, resulting to more effective soil protection to erosion (Trimble, 1990; Kosmas et al., 2000a).

However, simultaneous stopping of traditional land management practices results in soil erosion increase (Morgan and Rickson, 1990). Specifically, on sloping lands, an important abandonment of conservation practices, which are applied on traditional drystone terraces, is recorded (Giourga, 1991; Schembri, 1997).

A field study was conducted for 2 years, in Lesvos Island, Greece, in order to research the evolution of natural resources such as soil and vegetation, following land abandonment, considering three land uses, cultivation, short-time abandonment and long-time abandonment. The main target was to obtain reliable conclusions for ecosystems' management in the Mediterranean basin.

2. Materials and methods

The research was conducted in Lesvos Island, which is situated in the Aegean Sea, Greece. The study area is part of a watershed with total area 19.401 ha on the east side of Gera Gulf. The area has steep slopes and a total elevation of 600 m. The substratum comprises water permeable marbles and schists. The climate of the area is dry to sub-humid Mediterranean according to Thornwaite's classification (Karras, 1973) with moderate water excess during winter affected by the surrounding sea. Also, the existing long-term weather data of the eastern part of the island and data from conducted measurements suggest a dry sub-humid climate, according to FAO-UNESCO (1997) climatic regimes classification system (Kosmas et al., 2000b). From data results, that mean annual rainfall from 1994 to 2001 was 644 mm and mean rainfall sum from October to May (period of the year during which rainfalls are recorded each year in the region) was 596 mm. Potential evapotranspiration ranges from 855 to 997 mm.

Olive cultivation is the main productive activity in agricultural sector of the Island's economy, with olive groves covering 80% of agricultural land occupied by 11 millions of olive trees (N.S.S.G., 1993; N.S.S.G., 1998). It is impressive to note that foreign travelers of the 19th century, crossing Lesvos named Gera Gulf as "Olivier" in their manuscripts. The extensive monoculture of olive trees in the region is dated back in 1850 when the old cultivations were damaged by frost (Paraskeuaidis, 1996; Bakker et al., 2005; Kizos and Koulouri, 2005).

To determine water erosivity selected parameters were measured such as rainfall characteristics (height, duration), sediment losses and runoff volume. To determine soil erodibility vegetation parameters (woody shrubs vegetation cover, biomass production of annuals, shrub vegetation composition and diversity), soil parameters (texture, organic matter, bulk density, porosity, surface stoniness), slope profile description parameters (slope, slope length) and terraces parameters (configuration, ruined structure percentage) were measured.

The Gerlach sampling field method (Gerlach, 1967; Leopold and Emmet, 1967) suitable for no ploughed soils was used for runoff and sediment losses collection (Lopez-Bermudez, 1990). Sediment losses were collected every month and runoff was collected after every rainfall event. Meteorological data were collected from Mitilini Airport National Meteorological Station, on a 5-min basis.

The experimental design was based on the selection of two basic factors, "land use" and "slope gradient". For the study of land abandonment, three land uses in terraced olive groves were distinguished: (a) cultivation, (b) short-time abandonment for 5 years when low woody shrubs of typical Mediterranean vegetation named "frygana" are regenerated and (c) long-time abandonment after 20 years when the native vegetation of tall shrubs and trees called "maquis" are regenerated.

The selection of the three land uses was based on the fact that, when cultivation stops and no other disturbance such as fire or grazing follows, a typical vegetation successive process takes place and annuals, perennials, shrubs and trees are established (Grime, 2001). At the same time, the olive trees lose their "cultivated" character and turn to wild ones. Usually abandoned olive groves turn to dense Mediterranean shrublands between 9 and 15 years (Beaufoy, 2000) and on that state only the remaining terraces indicate that the area was cultivated (Theodorakakis, 1995). Considering that the impact of abandonment on ecosystems function and structure is changing in relation to time and the changes cover time lags of decades (Elwell and Stocking, 1976; Francis and Thornes, 1990; Theodorakakis, 1995), it is not possible to study these changes in the same area. Instead the three different land uses were studied in separate areas (Cammeraat and Imeson, 1998).

Slope gradient is a very important factor affecting soil erosion intensity (Zachar, 1982; Morgan, 1986; Fox and Rorke, 1999). In this study, it was decided that the sampling sites would have specific slope gradient so that the results could be comparable. Two slope gradients were selected, slope gradient 25% referred as "steep slope" and slope gradient 40% referred as "very steep slope" according to the following criteria:

a. the range of slope gradients where olive groves in the Mediterranean basin are planted, from 0% to 60% (N.S.S.G., 1993; Theodorakakis, 1995; Margaris et al., 1996;

King et al., 1997; Pratt and Funnell, 1997; N.S.S.G., 1998; Beaufoy, 2000; Grove and Rackham, 2001),

b. the range of slope gradients where traditional terraces are constructed, from 10% to 50% (Bostanoglou, 1976; Papamichos, 1985; Schwab et al., 1993; Rackham and Moody, 1996; Poesen and Hooke, 1997),
c. the range of slope gradients where cultivation is abandoned, greater than 40% (Morgan, 1986; Valmis, 1990; Theodorakakis, 1995; Margaris et al., 1996; Pratt and Funnell, 1997; Grove and Rackham, 2001),
d. classes of slope gradients as they are classified by USDA (United States Department of Agriculture),
e. classes of slope gradients as they are classified by studies for the Mediterranean region (Kosmas et al., 2000b).

Runoff plot slope length was chosen at 10 m, according to the specific soil erosion measurement method for the Mediterranean shrub-type ecosystems (Gerlach, 1967; Leopold and Emmet, 1967). The main terraces' characteristic of the traditional construction technique, in extensive tree cultivation, is that the slope gradient remains between subsequent terraces (Beaufoy, 2000) (Fig. 1). This is probably because there was no need for level land in tree cultivation while the technique was differentiated according to geology, slope gradient and type of cultivation. Construction style and manner was probably a matter of custom (practice) and fashion (Moody and Grove, 1990). So slope length was measured downwards from the upper terrace feet and slope was the angle of this area (Fig. 1).

The spatial organization of sampling sites was based on the field manual of MEDALUS E.U. program. Every sampling site had total area of 30 m * 30 m and was divided up to nine sub-areas (Cammeraat, 1998). In every sampling station, three sediment troughs were installed in line.

To ensure representative and repetitive sampling (Roels and Jonker, 1983; Nearing et al., 1999), three replications of the two variable combinations (for example three replications of cultivated plots with steep slope) were selected, ending to 18 sampling stations while non-proportional, stratified, random sampling was applied (Gareth, 1987; Benos, 1991).

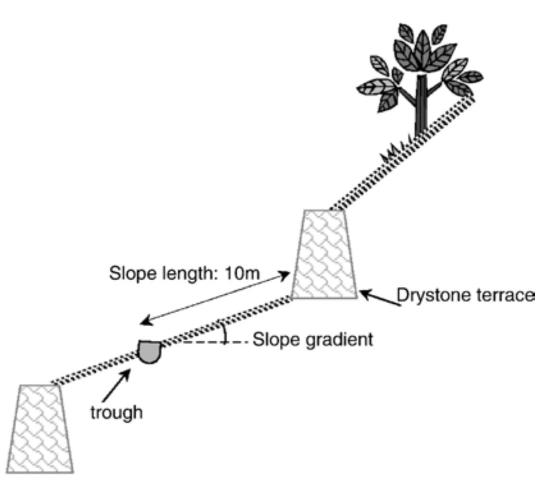

Fig. 1. Representation of the experimental plot section illustrating soil slope, slope length and trough installation.

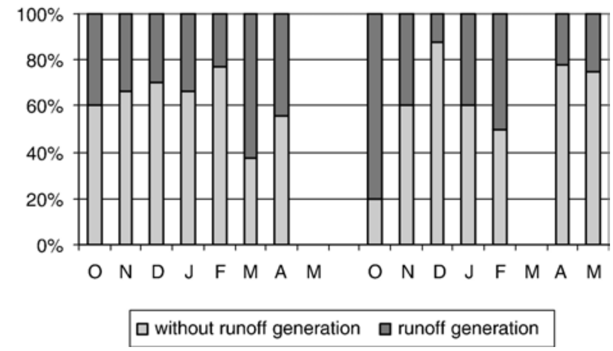

Fig. 2. The percentage of rainfall events that induced or did not induced runoff during the experimental period.

In order to conclude to reliable conclusions and to avoid interpreting data in an arbitrary way the collected data were statistically analyzed. Statistical analysis comprises tests to identify statistical significant differences among populations (Samuels and Witmer, 1999; Waite, 2000). Tests applied were parametric or nonparametric according to sample size and the validity of the normal distribution requirement. In every conducted test, only statistical significant differences were annotated and used for results interpretation. For testing relationships between two variables, correlation coefficients were computed.

3. Results and discussion

The first year of the experiment rainfall sum from October to May was 464 mm and 63 rainfall events were recorded and the second year it was 497 mm and just 42 rainfall events were recorded, when mean value from 1994 to 2001 is 596 mm with a standard deviation of ±150 mm. It is worth mentioning that rainfall was higher in the second year despite the fewer rainfall events.

From the rainfall events recorded, only a proportion generated water runoff and therefore soil erosion. Such rainfalls had amounts greater than 0.7 mm and duration exceeding 25 min (Fig. 2).

Soils in all sampling sites have clayey texture, except two short-time abandonment sites one on steep slope and one on very steep slope where texture is clay-loamy. Average organic matter contents are similar between land uses ranging from 5.4% to 7.8%, percentages that are considered to be regular for Mediterranean ecosystems with natural vegetation (Morgan, 1986; Tate, 1987; Descroix et al., 2001) although that someone would expect a lower content in cultivated soils. The high content in cultivated ecosystems might be attributed to the low intensity of cultivation in the olive groves in comparison with arable cultivations (Beaufoy, 2000; Loumou and Giourga, 2002).

Table 1
Descriptive statistics for soil properties, vegetation parameters and terraces characteristics according to land use and soil slope

Land use	Bulk density (g/cm^3)	Porosity (%)	Organic matter (%)
Slope gradient 25%			
Cultivation	1.4	46	5.1
Short-time abandonment	1.2	55	7.8
Long-time abandonment	1.7	36	6.6
Slope gradient 40%			
Cultivation	1.3	49	6.7
Short-time abandonment	1.2	55	5.4
Long-time abandonment	1.8	32	7.1

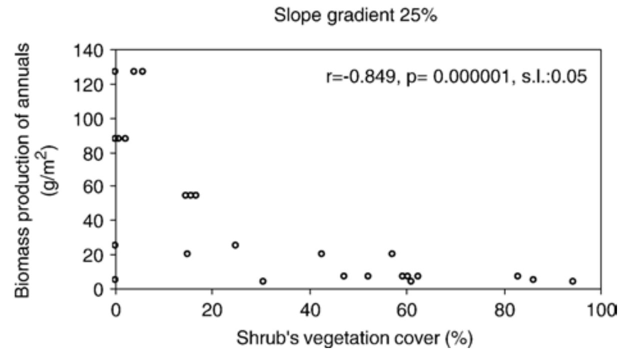

Fig. 4. Biomass production of annuals (g/m^2) and shrub's vegetation cover (%) relationships measured in the three land uses on steep slope gradient (25%).

Soil erodibility in all land uses is expected to be low because of clayey, clay-loamy soil texture and high organic matter content. Furthermore, in long-time abandonment sites, bulk density is greater and porosity is smaller than in cultivated and short-time abandonment sites (Alifragis and Papamihos, 1995), so that soils in long-time abandonment sites are expected to be more erodible than the other two land uses (Table 1).

Biodiversity of shrub vegetation is lower in cultivated ecosystems with a Shannon's index value of 0.91 (Magurran, 1988), increasing in short-time abandonment to 0.93 and long-time abandonment ecosystems have the highest biodiversity with index values up to 1.20 (one-way ANOVA: $p=0.046*10^{-4}$, s.l.: 0.05). The vegetation composition recorded at the sampling stations indicated that in short-time abandonment there are one or two dominant woody shrub species *Thymus capitatus* or *Cistus creticus*, covering up to 60% of sampling area. In long -time abandonment ecosystems, there are two dominant shrub species *Quercus coccifera* and *C. creticus* covering up to 80% of sampling area. In both, these land uses vegetation cover of the other plant species is limited.

In the land uses with steep slope gradient (25%), as years after abandonment are added, shrubs' vegetation cover is increasing (Kruskal–Wallis: $p=0.002$, s.l.: 0.05) from 6% in cultivation to 36% in short-time abandonment plots up to 64% in long-time abandonment plots, and biomass production of annuals is decreasing (Kruskal–Wallis: $p=0.134*10^{-7}$, s.l.: 0.05), from 75 g/m^2 in cultivated plots to 17 g/m^2 in short-time abandonment plots down to 8 g/m^2 in long-time abandonment plots (Fig. 3). The two parameters are associated with a negative correlation coefficient (Spearman's $r=-0.849$, $p=0.00001$, s.l.: 0.05) (Fig. 4). In Mediterranean ecosystems vegetation cover of shrub and annual plant species are correlated negatively and a climax state of balance is obtained (Spetch et al., 1983), while natural vegetation regenerates after cultivation interruption and shrub species are acting competitively to annual plant species for natural recourses such as nutrients, water and soil (Giourga et al., 1998; Grime, 2001).

Surface stoniness percentage is increasing (Kruskal–Wallis: $p=0.027$, s.l.: 0.05) as years after land abandonment are increasing, from 2% in cultivated plots to 5% in short-time abandonment plots, up to 7% in long-time abandonment plots (Fig. 3). This is either due to high selective erosion intensity over longer time spans, resulting in revealing bedrock material or due to cultivators who choose to abandon lands with high surface stoniness percentage, considering them as lands of lower productivity (Poesen and Bunte, 1996; Poesen et al., 1999). Also it is well possible

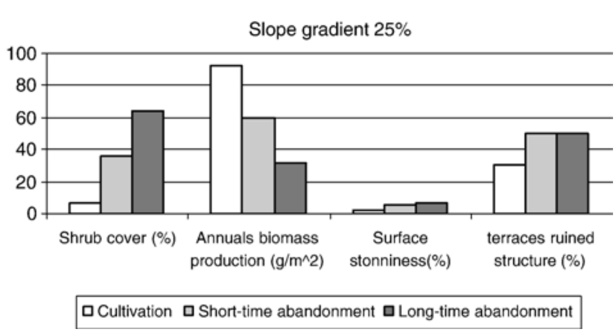

Fig. 3. The parameters shrub vegetation cover (%), biomass production of annuals (g/m^2), surface stoniness (%) and terraces ruined structure (%) for ecosystems with steep slope gradient (25%).

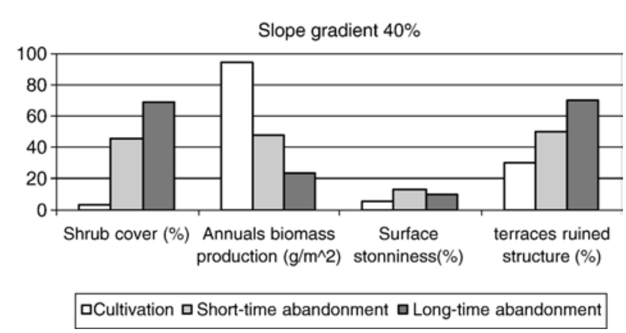

Fig. 5. The parameters shrub vegetation cover (%), biomass production of annuals (g/m^2), surface stoniness (%) and terraces ruined structure (%) for ecosystems with very steep slope gradient (40%).

that arable soils were reclaimed by removing the largest rock fragments–a common practice in the Mediterranean–resulting in a low surface stone cover (Poesen et al., 1998).

As expected, ruined structure percentage of terraces increases (Kruskal–Wallis: $p=0.022$, s.l.: 0.05) as years after abandonment increase. In cultivated plots, values recorded were ranging between 20% and 40% and in abandoned plots values rise and range from 40% up to 60% (Fig. 3). Field monitoring resulted that the terrace configuration in abandoned lands is usually braided (successive) and in cultivated lands is usually parallel, indicating that lands with braided (successive) terraces are selected for abandonment probably because it is more difficult there to apply cultivation practices (Grove and Rackham, 2001).

In the land uses with very steep slope gradient (40%), for the parameters shrub vegetation cover (Kruskal–Wallis: $p=0.013*10^{-6}$, s.l.: 0.05), and biomass production of annuals (Kruskal–Wallis: $p=0.161*10^{-3}$, s.l.: 0.05) were recorded the same conditions as in land uses with steep slope (Fig. 5). The two parameters are also related with a negative correlation coefficient (Spearman's $r=-0.662$, $p=0.0003$, s.l.: 0.05) (Fig. 6). Ruined terrace structures are increasing (Kruskal–Wallis: $p=0.022$, s.l.: 0.05) as years after abandonment are added and values range from 20% to 40% in cultivation land use, from 40% to 60% in short-time abandonment land use and the higher values were recorded in long-time abandonment land use from 60% up to 80% (Fig. 5). As to surface stoniness percentage parameter the values are similar between land uses (Kruskal–Wallis: $p=0.100$, s.l.: 0.05) ranging from 6% to 13%, probably because steep slope gradient results in soil movement downwards to gentle slope gradients, resulting to bedrock revealing irrespective of land use (Poesen, 1995; Poesen et al., 1998) (Fig. 5).

Annual runoff values measured ranged from 14 m^3/ha to 25 m^3/ha with mean value 20 m^3/ha and standard deviation 17 m^3/ha. The values are similar between the three land uses although land cover parameters such as soil and vegetation properties vary (Kruskal–Wallis: slope gradient 25%: $p=0.525$, s.l.: 0.05; slope gradient 40%: $p=0.111$, s.l.: 0.05) (Table 2).

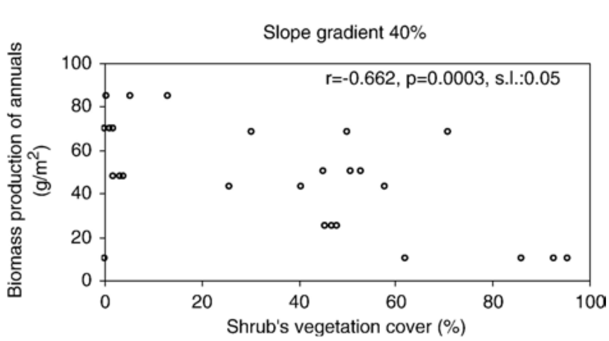

Fig. 6. Biomass production of annuals (g/m^2) and shrub's vegetation cover (%) relationships measured in the three land uses on very steep slope gradient (40%).

Table 2
Annual runoff descriptive statistics (m^3/ha), according to land use and slope gradient

		Slope 25%	Slope 40%	Overall slope gradients
Cultivation	Mean	20	25	23
	Standard deviation	(15)	(15)	(15)
Short-time abandonment	Mean	25	24	24
	Standard deviation	(19)	(26)	(23)
Long-time abandonment	Mean	16	14	15
	Standard deviation	(12)	(11)	(11)
Overall land uses	Mean	20	21	21
	Standard deviation	(16)	(19)	(17)

One conclusion resulting from above is that the retentions (infiltration, interception by surface vegetation cover, depression storage, ponding, evaporation) of the hydrologic cycle (Novotny and Chesters, 1981; Llorens et al., 1992) and mainly infiltration, which is the most important retention of rainfall water in the Mediterranean ecosystems (Maidment, 1993; Duiker et al., 2001), are also similar. Another concluding statement is that bulk density and soil porosity values which mentioned in long-time abandonment plots are insignificant for soil erodibility.

Runoff values are also similar between different slope gradients in all land uses (Mann–Whitney U: cultivation: $p=0.527$, s.l.: 0.05; short-time abandonment: $p=0.467$, s.l.: 0.05; long-time abandonment: $p=0.448$, s.l.: 0.05) (Table 2) because slope gradient affects the velocity of runoff water and does not affect the retentions nor the runoff volume (Ward and Elliot, 1995).

Mean annual soil erosion measured was 41 kg/ha with high standard deviation (66 kg/ha) due to extreme soil erosion values, which have been generated mainly during intense rainfall events, or in few cases probably by soil surface disturbance by animals, ants or humans irrespective of land use and slope (Table 3).

In Table 4, measured soil erosion values from previous studies in the same area are shown, which are similar to those of the present study (Arhonditsis et al., 2000; Arhonditsis et al., 2002). It should be mentioned that the higher values in natural shrub vegetation are due to the absence of terraces. In other studies in Mediterranean ecosystems values measured for similar land uses (Francis, 1990; Kosmas et al., 1997) agree with the values from this study. From this collation, it is concluded that soil erosion is comparatively lower in abandoned cultivations with terraces and in natural shrublands in comparison with values measured in intensive cultivations such as vines and eucalyptus plantations. Another very important point to be mentioned is that although soil erosion is low on terraced lands it isn't eliminated.

Annual soil erosion was different between the three land uses with steep slope gradient (25%) (Kruskal–Wallis test:

$p=0.002$, s.l.$=0.05$); more specifically, it was lower in cultivated olive groves (12 kg/ha), it was increasing in short-time abandonment ecosystems (19 kg/ha), and the greatest values were measured in long-time abandonment ecosystems (44 kg/ha) (Table 3).

The fact that soil erosion is increasing as the years after abandonment are added is recorded mainly because ecosystem parameters regarding vegetation are changing. Specifically, as noted above, biomass of annual plants is decreasing and shrubs vegetation cover is increasing because of vegetation lifeforms competition. So in shrub areas soil surface is covered only by foliage, which is leveled 20 cm above soil surface, and the area below remains bare of other vegetation cover (low shrubs or annuals) (Spetch et al., 1983; Cerda, 1998), resulting in increased soil sediment removal. At the same time, shrub vegetation forms foliage gaps, because it is growing in accumulated tufts and annual plants, because of resource competition, are sparsely covering remaining gaps, which become areas of runoff accumulation (Sanchez and Puigdefabregas, 1994; Cammeraat and Imeson, 1999; Bergkamp et al., 1999), resulting also to increased soil sediment removal. So the final result is increased soil erosion in the soil patches covered by shrubs vegetation.

On the contrary, in areas where annual plant species dominate on soil surface, there is a thick root layer covering and accumulating the first centimeters of soil surface where runoff acts on (Zachar, 1982; Mutter and Burnham, 1990; Sarlis, 1998; Graaff and Eppink, 1999), resulting in soil erosion decrease (Morgan, 1986). So soil patches covered by annuals have lower soil erosion than patches covered by shrubs and those with shrubs have lower soil erosion than patches of bare soil.

Another cause of increasing annual soil erosion from cultivation to long-time abandonment is the higher percentages of ruined terraces' structures. When the terrace structure is ruined, runoff is concentrated on damaged spots resulting in increased soil sediment removal (Gallart et al., 1994; Ramos and Porta, 1997).

Table 3
Descriptive statistics for annual soil erosion (kg/ha), according to land use and slope gradient

		Slope 25%	Slope 40%	Overall slope gradients
Cultivation	Mean	12	54	33
	Standard deviation	(19)	(45)	(40)
Short-time abandonment	Mean	19	69	44
	Standard deviation	(14)	(130)	(95)
Long-time abandonment	Mean	44	46	45
	Standard deviation	(54)	(53)	(53)
Overall land uses	Mean	25	56	41
	Standard deviation	(36)	(84)	(66)

Table 4
Mean annual soil erosion (kg/ha) measured for several land uses in Mediterranean ecosystems

Reference	Land use	Mean soil erosion (kg/ha)
Arhonditsis et al. (2000)	Shrubland (maquis)	204
Arhonditsis et al. (2002)	Abandoned olive grove (5 years)	30
	Cultivated olive grove	65
	Grazed olive grove	55
Francis (1990)	Abandoned cultivation—1 year	24
	Abandoned cultivation—2 years	32
	Abandoned cultivation—5 years	41
	Abandoned cultivation—20 years	19
Kosmas et al. (1997)	Cereals	176
	Vines	1428
	Eucalyptus plantation	238
	Shrubland (maquis)	67
	Abandoned olive grove (short-time)	8

However, when the slope gradient is very steep (40%), soil erosion does not increase but remains at similar high levels between cultivation, short-time abandonment and long-time abandonment. The effect of the slope gradient high value on soil erosion and sediment losses is so significant that it revokes the protection provided by vegetation or soil properties (Zachar, 1982; Morgan, 1986; Kosmas et al., 1999) (Fig. 5). Annual soil erosion is similar between the three land uses (Kruskal–Wallis test: $p=0.051$, s.l.: 0.05) and values measured were 56 kg/ha with standard deviation of 84 kg/ha (Table 3).

Soil erosion is significantly higher on very steep slope gradient (40%) than on steep slope gradient (25%) only in cultivated ecosystems (Mann–Whitney U: $p=0.0001$, s.l.: 0.05) (Table 3), a result which is attributed partially to the fact that in cultivated very steep sloped areas, terrace configuration is braided (successive) and soil sediment transfer is more intense. In abandoned lands with very steep slope gradient, there is no difference recorded between the two slope gradients because there is a greater biomass production of annuals, which counteracts high soil gradient effect (Figs. 3 and 5).

4. Conclusions

The impact of abandonment of traditional extensive cultivation in the Mediterranean basin on soil sediment losses differentiates according to slope gradient. When slope gradient is steep (25%), soil erosion is increasing significantly after abandonment because of the changes in vegetation cover characteristics. The dense protective cover of annual plants decreases while, shrub vegetation cover increases and bare soil surface below shrub's foliage increases too. At the same time, drystone terraces supporting soil material and runoff water collapse. The combination of these changes results to deficient soil protection and increased soil particles removal.

On very steep slope gradients (40%), there is a different treatment while soil sediment losses remain at the same high levels after abandonment, although soil and vegetation properties are altering. Therefore, when the slope gradient is very steep (40%), it constitutes the main factor determining soil sediment losses, surmounting land use effect.

Biomass production of annuals in cultivated olive groves has mean value of 70 g/m^2 with standard deviation ±40 g/m^2, a value within the range for those of Mediterranean pastures 50–380 g/m^2 (Sarlis, 1998), indicating a low intensity traditional cultivation with limited agricultural practices applied, such as ploughing and pest control (Guzman, 1999). Consequently, cultivation conditions in olive groves could be characterized as especially rare, with dense undisturbed vegetation cover of annual plant species occurring due to minimum application of agricultural practices. The result is an ecosystem more similar to a pasture than to a tree plantation.

Furthermore, some useful facts came out from this study according to land uses' characteristics. Long-time abandoned ecosystems have high surface stoniness percentage and mainly braided (successive) terraces affecting negatively access and application of cultivation practices. Short-time abandonment ecosystems have higher surface stoniness percentages indicating low productivity, inaccessibility and misapplication of cultivation practices. Cultivated ecosystems have low surface stoniness percentage and mainly parallel terraces configuration.

Another very important conclusion is that Mediterranean traditional drystone terraces do not protect the soil surface from water erosion completely, because of the existing slope gradient between two successive terraces (Foster and Highfill, 1983).

With regard to ecosystems' management in the Mediterranean basin, the results indicate that traditional extensive cultivation on terraced sloping lands could be an integrated agricultural land management action with limited impacts on ecosystems' functions, resulting in soil and water recourses conservation.

References

Alias, L.J., Lopez-Bermudez, F., Marin-Sanleandro, P., Romero-Diaz, M.A., Martinez, J., 1997. Clay minerals and soil fertility loss on Peric Calcisol under a semiarid Mediterranean environment. Soil Technology 10, 9–19.

Alifragis, D., Papamihos, N., 1995. In: Dedousi, Thessaloniki (Ed.), Description-Sampling-Laboratory Analysis for Forest Soils and Plant Tissues (in Greek).

Arhonditsis, G., Giourga, Ch., Loumou, A., 2000. Ecological patterns and comparative nutrient dynamics of natural and agricultural Mediterranean-type ecosystems. Environmental Management 26 (5), 527–537.

Arhonditsis, G., Giourgia, Ch., Loumou, A., Koulouri, M., 2002. Quantitative assessment of agricultural runoff and soil erosion using mathematical modeling: applications in the Mediterranean region. Environmental Management 30 (3), 434–453.

Bakker, M.M., Govers, G., Kosmas, C., Vanacker, V., Oost, K. (van), Rounsevell, M., 2005. Soil erosion as a driver of land use change. Agriculture Ecosystems and Environment 105, 467–481.

Beaufoy, G., 2000. The environmental impact of olive oil production in the European Union: practical options for improving the environmental impact. European Forum on Nature Conservation and Pastoralism and the Asociación para el analisis y reforma de la política agro-rural, Final Report. www.europa.eu.int.com/agriculture.

Benos, V.K., 1991. In: Stamoulis, Athens (Ed.), Methods and Sampling Techniques (in Greek).

Bergkamp, G., Cedra, A., Imeson, A.C., 1999. Magnitude–frequency analysis of water redistribution along a climate gradient in Spain. Catena 37, 129–146.

Bostanoglou, L., 1976. Restoration and protection of degraded slopes. Conservation in Arid and Semiarid Zones, F.A.O. Conservation Guide, Rome.

Cammeraat, L.H., 1998. MEDALUS-Field Manual, Version 4. September.

Cammeraat, L.H., Imeson, A.C., 1998. Deriving indicators of soil degradation from soil aggregation studies in southeastern Spain and southern France. Geomorphology 23, 307–321.

Cammeraat, L.H., Imeson, A.C., 1999. The evolution and significance of soil-vegetation patterns following land abandonment and fire in Spain. Catena 37, 107–127.

Cerda, A., 1998. The influence of aspect and vegetation on seasonal changes in erosion under rainfall simulation on a clay soil in Spain. Canadian Journal of Soil Science 78, 321–330.

Descroix, L., Viramontes, D., Vauclin, M., Gonzales Barrios, J.L., Esteves, M., 2001. Influence of soil surface features and vegetation on runoff and erosion in the Western Sierra Madre (Durango, northwest Mexico). Catena 43, 115–135.

Duiker, S.W., Flanagan, D.C., Lal, R., 2001. Erodibility and infiltration characteristics of five major soils of southwest Spain. Catena 45, 103–121.

Elwell, H.A., Stocking, M.A., 1976. Vegetal cover to estimate soil erosion hazard in Rhodesia. Geoderma 15, 61–70.

Foster, G.R., Highfill, R.E., 1983. Effect of terraces on soil loss: USLE P factor values for terraces. Journal of Soil and Water Conservation 38, 48–51.

Fox, D.M., Rorke, B.B., 1999. The relationship of soil loss by interrill erosion to slope gradient. Catena 38, 211–222.

Francis, C.F., 1990. Soil erosion and organic matter losses on fallow land: a case study from south-east Spain. In: Boardman, J., Foster, I.D.L., Dearing, J.A. (Eds.), Soil Erosion on Agricultural Land. J. Wiley.

Francis, C.F., Thornes, J.B., 1990. Runoff hydrographs from three Mediterranean vegetation cover types. In: Thornes, J.B. (Ed.), Vegetation and Erosion-Processes and Environments. J. Wiley.

Gallart, F., Llorens, P., Larton, J., 1994. Studying the role of old agricultural terraces on runoff generation in a small Mediterranean mountainous basin. Journal of Hydrology 159, 291–303.

Gareth, W., 1987. Techniques and Fieldwork in Ecology. Bell and Hyman Ltd.

Gerlach, T., 1967. Hillslope troughs for measuring sediment movement. Revue Geomorphologic Dynamique 17, 172.

Giourga, Ch., 1991. Change of traditional land management model in Aegean Archipelago—impacts on island ecosystems. Ph.D. Thesis, University of the Aegean, Department of Environmental Studies, Lesvos, Greece (in Greek).

Giourga, Ch., Margaris, N., Vokou, D., 1998. Effects of grazing pressure on succession process and productivity of old fields on Mediterranean islands. Environmental Management 22 (4), 589–596.

Graaff, J., Eppink, L.A.A.J., 1999. Olive oil production and soil conservation in southern Spain, in relation to EU subsidy policies. Land Use Policy 16, 259–267.

Grime, J.P., 2001. Plant Strategies, Vegetation Processes and Ecosystem Properties, Second Edition. John Wiley and Sons.

Grove, A.O., Rackham, O., 2001. The Nature of Mediterranean Europe, An Ecological History. Yale University Press.

Guzman, Alvarez, 1999. Olive cultivation and ecology: the situation in Spain. OLIVAE 78, 41–49.

Hatzopoulos, J.N., Giourga, Ch., Koukoulas, S., Margaris, N., 1992. Land cover classification of olive trees in Greek islands using Landsat-TM images. Proceedings of the ASPRS at the International conference in Washington D.C. 2–7 August.

Karras, G.S., 1973. Climatic classification of Greece according to Thornthwaite method. PhD Thesis, Athens (in Greek).

King, R., Proudfood, L., Smith, B., 1997. The Mediterranean-Environment and Society. Halsted Press, U. K.

Kizos, A., Koulouri, M., 2005. Economy, demographic changes and morphological transformation of the agri-cultural landscape of Lesvos, Greece. Human Ecology Review 12 (No 2), 183–192.

Kosmas, C., 1995. Field site: Spata, Greece. MEDALUS II-Project 1, Basic Field Program, Final Report Covering the Period "1 January 1991 to 1 September 1995".

Kosmas, C., Danalatos, N., Cammeraat, L.H., Chabart, M., Diamantopoulos, J., Farand, R., Gutierrez, L., Jacob, A., Marques, H., Martinez-Fernandez, J., Mizara, A., Moustakas, Nn., Nikolaou, J.M., Oliveros, C., Pinna, G., Puddu, R., Puigdefabregas, J., Roxo, M., Simao, A., Stamou, G., Tomasi, N., Usai, D., Vacca, A., 1997. The effect of land use on runoff and soil erosion rates under Mediterranean conditions. Catena 29, 45–59.

Kosmas, C., Danalatos, N.G., Gerontidis, St., 2000a. The effect of land parameters on vegetation performance and degree of erosion under Mediterranean conditions. Catena 40, 3–17.

Kosmas, C., Gerintidis, St., Marathianou, M., 2000b. The effect of land use change on soils and vegetation over various lithological formations on Lesvos (Greece). Catena 40, 51–68.

Leopold, L.B., Emmet, W.W., 1967. On the design of a Gerlach trough. Revue Geomorphologic Dynamique 17, 173.

Llorens, P., Lattron, J., Gallart, F., 1992. Analysis of the role of agricultural abandoned terraces on the hydrology and sediment dynamics in a small mountainous basin (High Llobregat, East Pyrenees). Pirineos 139, 27–46.

Lopez-Bermudez, F., 1990. Soil erosion by water on the desertification of a semi arid Mediterranean fluvial basin: the Segura basin, Spain. Agriculture Ecosystems and Environment 33, 129–145.

Loumou, A., Giourga, Ch., 2002. Olive groves: "The life and identity of the Mediterranean". Agriculture and Human Values 00, 1–9.

Magurran, A., 1988. Ecological Diversity and its Measurement. Chapman and Hall.

Maidment, D.R. (Ed.), 1993. Handbook of Hydrology. McGraw-Hill, INC.

Margaris, N.S., Koutsidou, E., Giourga, Ch., 1996. Changes in traditional Mediterranean land-use systems. In: Brant, C.J., Thornes, J.B. (Eds.), Mediterranean Desertification and Land Use. John Wiley and Sons Ltd, England.

Moody, J., Grove, A.T., 1990. Terraces and enclosure walls in the Cretan landscape. In: Bottema, S., Entjes-Nieborg, G., van Zeist, W. (Eds.), Mans' Role in the Shaping of the Eastern Mediterranean Landscape. Balkema, Rotterdam.

Morgan, R.P.C., 1986. Soil Erosion and Conservation. Longman Scientific and Technical.

Morgan, R.P.C., Rickson, R.J., 1990. Issues on soil erosion in Europe: the need for a soil conservation policy. In: Boardman, J., Foster, I.D.L., Dearing, J.A. (Eds.), Soil Erosion on Agricultural Land. Wiley.

Mutter, G.M., Burnham, C.P., 1990. Plot studies comparing water erosion on chalky and non-calcareous soils. In: Boardman, J., Foster, I.D.L., Dearng, J.A. (Eds.), Soil Erosion on Agricultural Land. John Willey and Sons.

N.S.S.G.—National Statistics Service of Greece, 1993. Agriculture-Livestock Census.

N.S.S.G.—National Statistics Service of Greece, 1998. Agriculture-Livestock Census.

Nearing, M.A., Govers, G., Norton, L.D., 1999. Variability in soil erosion data from replicated plot. Soil Science Society of America Journal 63, 1829–1835.

Novotny, V., Chesters, G., 1981. Handbook of Nonpoint Pollution: Sources and Management. D. Van Norstand.

Papamichos, Th.N., 1985. Forest Soils. Aristotel University of Thessaloniki, Thessaloniki. (in Greek).

Paraskeuaidis, P.S., 1996. Travelers for Lesvos-Third Edition. Mitilini. (in Greek).

Poesen, J., 1995. Stony soils. MEDALUS—Basic Field Program—Final Report Covering the Period 1 January 1991 to 30 September 1995. EV5V-CT92-0128.

Poesen, J., Bunte, K., 1996. The effects of rock fragment on desertification processes in Mediterranean environments. In: Brant, J., Thornes, J. (Eds.), Mediterranean Desertification and Land Use. John Wiley and Sons.

Poesen, J., Hooke, J., 1997. Erosion, flooding and channel management in Mediterranean environments of Southern Europe. Progress in Physical Geography 21 (2), 157–199.

Poesen, J., Wesemael, B., Bunte, K., Benet, A., 1998. Variation of rock fragment cover and size along semiarid hillslopes: a case study from southeast Spain. Geomorphology 23, 323–335.

Poesen, J., De Luna, E., Franca, A., Nachtergaele, J., Govers, G., 1999. Concentrated flow erosion rates as affected by rock fragment cover and initial soil moisture content. Catena 36, 315–329.

Pratt, J., Funnell, D., 1997. The modernization of Mediterranean agriculture. In: King, R., Proudfood, L., Smith, B. (Eds.), The Mediterranean-Environment and Society. Halsted Press, U.K.

Rackham, O., Moody, J., 1996. The Making of the Cretan Landscape. Manchester University Press, New York.

Ramos, M.C., Porta, J., 1997. Analysis of design criteria for vineyard terraces in the Mediterranean area of north east Spain. Soil Technology 10, 155–166.

Roels, J.M., Jonker, P.J., 1983. Probability sampling techniques for estimating soil erosion. Soil Science Society of America Journal 47, 1224–1228.

Samuels, M.L., Witmer, A.J., 1999. Statistics for the Life Sciences, Second edition. Prentice Hall.

Sanchez, G., Puigdefabregas, J., 1994. Interactions of plant growth and sediment movement on slopes in a semi arid environment. Geomorphology 9, 243–260.

Sarlis, G., 1998. Pastures improvement and management—Part A′. Ed Stamoulis, Athens (in Greek).

Schembri, P.J., 1997. The Maltese islands: climate, vegetation and landscape. Geojournal 41.2, 115–125.

Schwab, G.O., Fangmeier, D.D., Elliot, W.J., Frevert, R.K., 1993. Soil and Water Conservation Engineering. John Wiley and Sons, USA.

Spetch, R.L., Moll, E.J., Pressinger, F., Sommerville, J., 1983. Moisture regime and nutrient control of seasonal growth in Mediterranean ecosystems. In: Kruger, F.J., Mitchell, D.T., Jarvis, J.U.M. (Eds.), Mediterranean Type Ecosystems—The Role of Nutrients.

Tate, R., 1987. Soil Organic Matter—Biological and Ecological Effects. John Wiley and Sons.

The MEDALUS project—Mediterranean desertification and land use—manual on key indicators of desertification and mapping environmentally sensitive areas to desertification. In: Kosmas, C., Kirkby, M., Geeson, N. (Eds.), Directorate General Science, Research and Development, EUR 18882.

Theodorakakis, M.Ch., 1995. Structure. Dynamics and management on islands olive groves. Ph.D. Thesis, University of the Aegean, Department of Environmental Studies, Lesvos, Greece (in Greek).

Trimble, S.W., 1990. Geomorphic effects of vegetation cover and management: some time and space considerations in prediction of erosion and sediment yield. In: Thornes, J.B. (Ed.), Vegetation and Erosion Processes and Environments. John Wiley and Sons.

Valmis, S., 1990. Erosion—soils conservation, Ed. Stamoulis. Athens (in Greek).

Waite, S., 2000. Statistical Ecology in Practice—A Guide to Analyzing Environmental and Ecological Field Data. Pearson Education Limited.

Ward, A.D., Elliot, W.J. (Eds.), 1995. Environmental Hydrology. Lewis Publishers.

Wischmeier, V.H., 1960. Cropping-management factor evaluations for a universal soil-loss equation. Proceedings - Soil Science Society of America 24, 322–326.

Zachar, D., 1982. Soil Erosion. Developments in Soil Science, vol. 10. Elsevier.