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Soil Erosion in Extensive versus Intensive Land Uses in Areas Sensitive to Desertification: A Case Study in Beira Baixa, Portugal

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Abstract: The occurrence of long periods of drought followed by extreme episodes of rainfall and ineffective soil conservation practices are the main causes of soil erosion in the Mediterranean region. The objective of this paper is to assess and compare the hydrological and erosional responses related to land use changes in agricultural landscapes that are sensitive to erosion and that are a result of the significant replacement of traditional land uses. Such changes are characterized by the replacement of extensive olive groves associated with pastureland by intensive almond production, where deep plowing and heavy machinery are required. In each sampling site, runoff initiation, runoff coefficient, and soil loss were evaluated under simulated rainfall (55 mm h^{-1}), at plot scale (0.25 m^2), at the end of the hot and dry summer period. Slope gradient, soil texture, bulk density, soil organic matter content, soil water content, and plant cover were also determined. The results showed the impact of recently planted intensive almond orchards (IAOs) on accelerating soil erosion risk compared with the extensive traditional olive groves (EOGs), although runoff initiation and discharge are very similar between the studied land uses. The mean values recorded for soil loss and sediment concentration were 118 g m^{-2} h^{-1} and 12 g m^{-2} h^{-1} and 3.1 g L^{-1} and 0.7 g L^{-1}, respectively, for IAOs and EOGs. Our results also demonstrated that maintaining a vegetation cover is a determining factor for the prevention and control of soil erosion, especially in IAOs, where retaining high percentages of natural plant-residue mulch layers (>70%) reduced soil loss by about 70% in this study.

Keywords: soil erosion; intensive almond orchards; extensive olive groves; rainfall simulations; Portugal

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1. Introduction

Soil is a key resource for life and a vital component of Earth's ecosystems. Soils supply a great variety of goods, services, and resources to meet human needs [1–4], and are an essential item in the United Nations Sustainable Development Goals [5]. A sustainable society needs healthy soils to keep humans healthy [6]. Soil erosion is a worldwide concern and a major threat to achieving sustainability in agroecosystems [1,7–12].

Even though soil erosion varies with space and time, some drivers have been recognized as facilitating soil erosion: (i) the slope and length of hillsides [13,14]; (ii) shallow soils and highly erodible parent materials [15–17]; (iii) reduced water storage capacity or hydrophobicity [18]; (iv) long periods of drought followed by intense rainfall events [19–23]; (v) exposed soils without vegetation cover [19,20,24,25]; and (vi) the use of heavy machinery that compacts the top layers of soil [26].

Of these factors, precipitation leads the way in generating soil erosion, and higher intensity and more frequent rainfall events generally result in more severe soil erosion [11,22,23]. Several studies demonstrated that high-energy storms determined the annual soil loss [27,28].

Conversely, vegetation cover can affect soil erosion spatial patterns since increased vegetation cover can reduce the sensitivity to erosion [17,29]. Vegetation reduces the kinetic energy of raindrops through canopy interference or by the existence of litter, consequently reducing soil erosion [19,30], while root systems contribute to soil aggregation and thus help to reduce soil erosion [19]. Although soil type and topography have an important role in soil erosion, they are more stable than other factors [10,31]. Therefore, more attention should be paid to the impacts of rainfall and vegetation cover on soil erosion, especially in agricultural areas.

A recent review of soil erosion volumes in agricultural areas shows that degradation rates are several orders of magnitude faster than the soil formation rate [32–35], thus threatening the natural capital of soils [13] and promoting land degradation and desertification [36,37]. In Mediterranean areas, soil erosion is one of the most important processes driving land degradation [11,38] and thereby decreasing soil-related ecological services [39]. In this region, long periods of drought are followed by intense or even extreme rainfall events, which coincide with the disturbance of topsoil layers (e.g., by cultivation, intensive tillage, and plowing) or poor vegetation cover, very often in situations where good soil conservation practices are absent, a deleterious combination that promotes serious soil erosion [14,40,41]. Cereal crops and olive groves—traditional land uses in the Mediterranean region—are among the rainfed agricultural land uses that exhibit higher soil and water losses due to the impact of unsustainable practices, such as conventional tillage and plowing [19,20,41,42].

On the other hand, in Portugal, as in other Mediterranean countries, traditional land uses have been replaced by intensive land management practices in agricultural fields designed to develop an agricultural system that is more productive and economically viable. Such changes, mainly involving the expansion of olive and fruit orchards, are responsible for an increase in the use of herbicides and heavy machinery, which may promote soil and water degradation [13,43,44]. Studies carried out in intensive agriculture systems have found high erosion rates in avocado [45] and olive orchards [46–51], new citrus plantations [52,53], and vineyards [28,54–56]. Almond [13,57], persimmon [58,59], and apricot [5,60,61] orchards have also shown high erosion rates.

In Portugal, although most of the research on soil erosion has been carried out in areas occupied by rainfed cereal crops [19,20,42], more recently, it has considered the increasingly rapid expansion of intensive orchards, especially olive groves. Some studies have assessed how different management models can help to increase or mitigate soil loss with crops [62,63], mainly in the Alentejo region. However, little research has been carried out comparing traditional extensive land use vs. intensive land use management systems in Portugal.

The main objective of this work was to assess how changes in land use alter hydrological and erosional responses in Mediterranean agricultural landscapes when they result from changes in land use systems related to the increase in intensive almond orchards, based on irrigation and the use of heavy machinery. These have been replacing traditional uses that are dominated by extensive olive groves and coupled with pastureland. To achieve this goal, this study aimed to evaluate, under high-intensity rainfall simulations, (i) runoff initiation by measuring the time to runoff outlet in plot surfaces; (ii) runoff and sediment yield; and (iii) the influence of soil characteristics and vegetation cover on runoff and erosion. Understanding hydrogeomorphic processes at the pedon and hillslope scales is critical for planning and adopting soil management practices that decrease and control soil erosion risk [5,64–66] to help to reduce the risk of soil degradation.

2. Material and Methods

2.1. Study Area

The research was carried out in the municipality of Idanha-a-Nova in the Beira Baixa region, one of the areas in Portugal with high land degradation and susceptibility to desertification [67]. The Idanha-a-Nova municipality is located in central Portugal, close to the Spanish border (Figure 1). The substratum comprises mainly schist from the Schist Greywacke complex with poor, shallow soils, classified as dystric lithosols [68], and the predominance of an undulating relief with elevation ranging from 200 to 400 m a.s.l. Significant parts of the area dedicated to agriculture are associated with arkoses and sandstones and with ferric and orthic luvisols, characterized by greater depth and a horizon of clay accumulation at a certain depth.

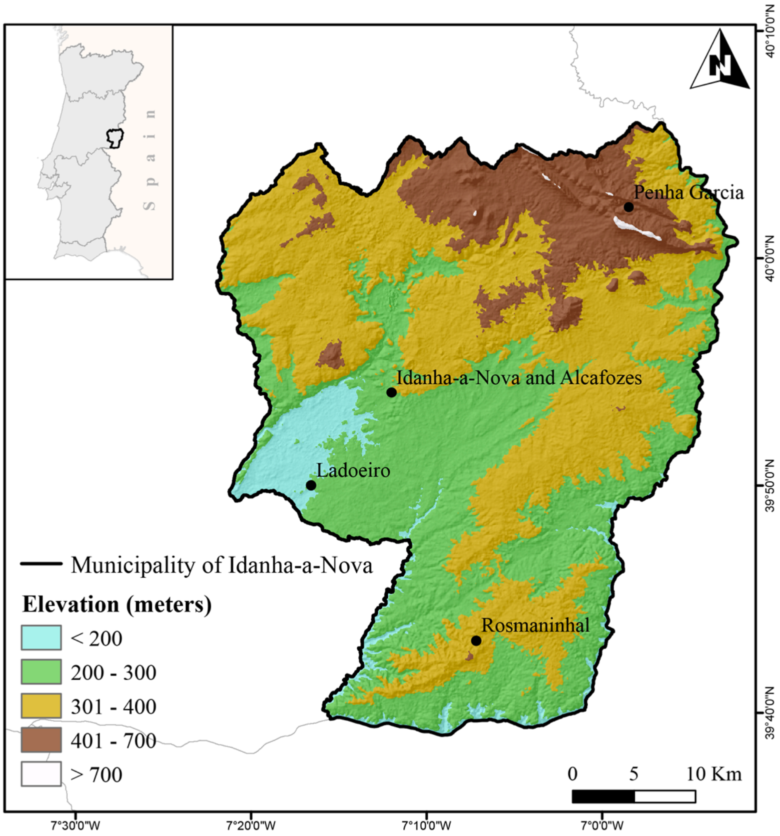

Figure 1. Location of the study area.

According to the Köppen climatic classification, the study area has a hot-summer Mediterranean climate (Csa), characterized by wet, cool winters (10 °C average temperature) and hot, dry summers (25.7 °C average maximum temperature for summer). The mean annual precipitation of 600 mm has high inter-annual variability and a seasonal concentration pattern. The wettest periods of the year are in autumn and winter, between October and February, while the dry period lasts between May and September.

This variability reflects the seasonal pattern typical of the Mediterranean region, with rainfall concentrated in the autumn and winter months. Considering the 12.7 mm threshold proposed by Renard et al. [69] to define precipitation events that have erosive power, daily and hourly precipitation were analyzed for the study area for the period 2002–2020. As we can see in Figure 2, most of the daily erosive rainfall occurred in October and November, with a record around 30 days with more than 12.7 mm of rainfall for the period under analysis. Although there were not a significant number of days in September when precipitation exceeded 12.7 mm, when precipitation did occur in this month, there was a high probability that it would be concentrated in a short period of time (1 h) compared to the other months of the year.

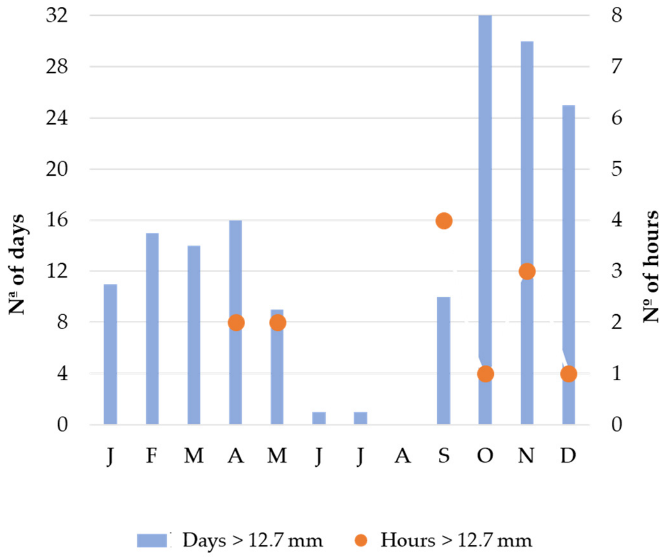

Figure 2. Daily and hourly precipitation events that have erosive power, according to Renard et al. [69], between 2002 and 2022, at the Ladoeiro meteorological station.

According to the agricultural and forestry map of Portugal produced by the Service of Agrarian Recognition and Management (SROA) [70], in the middle of the last century, cereal cultivation and extensive olive groves were the dominant land uses in the study area (%). As in most marginal areas of mainland Portugal, agricultural activities have become less important since the mid-20th century when a rural exodus took place, mainly because of poor conditions for agriculture (a Mediterranean climate and poor, shallow soils). The peripheral location of the study area, the lack of alternative employment sectors, and the fact that a great many farm owners were elderly were also determinants [23].

Not even the installation of the Idanha irrigation perimeter in the 1950s, supported by the construction of the Marechal Carmona dam, which was intended to benefit an area of approximately 8300 hectares, managed to stop the agricultural land abandonment that was already being felt at that time. For several decades, forage and cereal crops were the most irrigated crops. However, in the last decade, there has been a very significant transformation in the landscape resulting from the installation of intensive and super-intensive orchards, mainly of almond trees. In 2018, the area occupied by orchards was around 250 ha [71]. In mid-2022, according to data obtained from satellite images, the area of irrigated orchards exceeded 2800 ha, mainly concentrated in the parishes of Ladoeiro (1078 ha) and Idanha-a-Nova and Alcafozes (1746 ha) [72]. These intensive orchards are sustained by the use of large amounts of water all year round. In fact, since 2018, and based on records from the perimeter irrigation system, the watering period, which generally lasted from April to October, has become annual (from January to December).

In 2018, Idanha-a-Nova was classified as a bio-region, the first in Portugal. According to the International Network of Eco Regions (INNER), “a bioregion is a sustainable management agreement of the territory based on organic agriculture” involving a whole local community.

2.2. Methodology

2.2.1. Definition of Land Use System Types/Subtypes Used in the Study Area

The study design aimed to obtain data to compare two different land use systems, one linked with traditional land use, based on traditional olive groves combined with pastureland, and the other involving intensive, irrigated almond orchards. The main characteristics of the selected land use systems are as follows:

Extensive olive groves (EOGs): This land use system has been providing a livelihood for people in the region for centuries. The plant density is low, with less than 200 trees per hectare. EOGs continue a traditional land use of the territory typically combined with pastureland for livestock and rarely for cereal crop production. The selected plots include olives groves combined with pastures where soil conservation measures were adopted, specifically no soil plowing and low or zero fertilization input. The traditional olive grove often develops on irregular, mainly hilly terrain. The harvesting and management are still mostly manual (Figure 3, left).

Figure 3. Example of extensive olive grove (**left**) and intensive almond orchard (**right**) in the study area.

Intensive almond orchards (IAOs): Intensive almond orchards have been introduced in the area in the last decade. These plantations are installed after the deep plowing and change of the local terrain, using heavy machinery and wheel traffic for harvesting and maintenance. They are treated intensively with the use of pesticides, herbicides, fertilizers, and irrigation. Plant density varies between 600 and 1600 almond trees per hectare, with less distance between trees and arrangement in parallel rows. Due to the shallow soils, most orchards are planted on ridges 30–40 cm high and 1 m wide to facilitate root establishment. To control annual weeds, herbicides or mowing are applied using heavy machinery. Consequently, at the end of the summer, we can find orchards with a natural plant-residue mulch layer resulting from the death of the grass stratum that has not been removed or soils without any kind of protective vegetation cover. To clarify the role of vegetation cover, the sampling design includes plots with different vegetation cover conditions, from plots with zero or a very low percentage of cover to others with a significant percentage of cover by herbaceous plants or a natural plant-residue mulch layer produced by mowing (Figure 3, right).

2.2.2. Rainfall Simulation Experiments

Rainfall simulation experiments have been widely used to evaluate runoff and sediment delivery [19,20,35,55,58]. Runoff and soil erosion were quantified with a small portable rainfall simulator based on the one described by Cerdà [73]. It consists of a springlink device placed 2 m above the soil, a small pump responsible for supplying water, and a wind protector to avoid changes in the direction of the rain droplets falling and the use of nozzles from Hardi (nozzle cone jet 1553/10). The pressure applied ranged from 1.5 to 1.6 kg cm^{-2}, which is equivalent to an average intensity of around 55 mm h^{-1}.

Twenty-two rainfall simulation experiments (eleven per land use system) were carried out for 1 h on circular plots (0.55 m in diameter, 0.25 m^2), covering different physical conditions (slope and stoniness) and, above all, grades of vegetation cover. In order to allow for comparisons between plots, all experiments were carried out at the end of the summer when the soil moisture was low (end of September 2021).

During the rainfall simulation experiments, the time required by runoff to reach the plot outlet was quantified in seconds (s). Runoff was then quantified gravimetrically at 2-min intervals (L m^{-2} h^{-1}) and the water volume was measured. The runoff coefficient (%) was estimated as the percentage of rainfall water running out of the circular plot, calculated by subtracting the total sprayed rainfall and collected runoff. In the laboratory, the total runoff was filtered using fine-meshed filter paper to determine, after drying at 105 °C, the sediment load (g m^{-2} h^{-1}) and concentration (g L $^{-1}$).

2.2.3. Soil Cover and Soil Analysis

Plant cover, resistance to penetration, and water repellency were measured prior to the rainfall simulation experiments. Vegetation cover (%) was quantified by visual interpretation, considering the total herbaceous cover and plant-residue mulch layer in the plot. Soil resistance was assessed using a pocket penetrometer. Soil water repellency was measured using the molarity of ethanol droplet (MED), as suggested by Doerr [74]. The ethanol concentrations used in this study area were 0, 1, 3, 5, 8.5, 13, 18, 24, and 36 percent, representing liquid surface tension intervals of approximately 5 dynes cm^{-1}. A zero value corresponded to hydrophilic (or wettable) soil and 36 percent corresponded to extremely water-repellent soils.

Soil samples (0–10 cm) were collected in the vicinity of the sampled plot to determine a few soil properties (grain size distribution, bulk density, soil organic matter, and soil moisture). Grain size distribution was defined after sieving the soil with a 2 mm mesh. The stone content (stoniness) was determined, and the fine fraction was used to obtain the soil texture (sand: 2 mm–63 µm; silt + clay: <63 µm). Dry bulk density was measured by the use of a cylindrical core of known volume. Soil organic matter was determined by the Tinsley method [75]. As the organic matter was very low (<2%) in all plots, this variable was not included in the analysis. Soil moisture was determined previously by the gravimetric method after drying samples (105 °C, 24 h). Local slopes (in %) were also measured with a digital clinometer.

2.3. Data Analyses

Descriptive statistics were determined for the plot and soil characteristics (average, standard deviation, maximum and minimum value and coefficient of variation). The results for the land use systems (extensive vs. intensive) in the hydrological response and soil erosion results were compared using general descriptive statistics and presented in box plot charts, allowing for the analysis of the values for the mean (dash lines), median, 25th, and 75th percentiles.

Prior to statistical comparisons, data normality was tested using the Shapiro–Wilk test. A p-value of <0.05 signified that the null hypothesis was rejected, indicating that the distribution was not normal. Of all the variables, only grain size distribution (silt, clay, and sand percentage) and herbaceous cover followed the Gaussian distribution. Several authors [76–78] consider that the alternative formulations of Levene's tests are robust against non-normality and they have been used for checking the homogeneity of variances. Thus, Levene's test was used to assess the equality of variances (homoscedasticity) between the average values in all the variables included in the study. Once the homoscedasticity had been evaluated, the Student's t-test was performed, aiming to compare means and estimate how significant the differences were. The null hypothesis assumed that no significant differences were identified between plots, considering soil properties, vegetation cover, and hydrologic and erosion responses for the two land use systems under study. Test results were considered significant at $p < 0.05$. Finally, in order to identify any possible influence of environmental plot variables on hydrological responses and soil erosion, Spearman's rank (Sr) correlations among the variables were performed. The IBM SPSS program (27.0 for Windows) was used to carry out the statistical analysis.

3. Results

3.1. Soil Properties and Vegetation Cover

Slopes ranged from 2 to 39% in the sampled plots, with the highest values recorded in the IAOs (Table 1). In fact, the IAOs registered a mean value of 19%, while the EOG plots had a mean value of 10%. Both Levene's test and the *t*-test showed *p*-values < 0.05, meaning that there were significant differences between the land use systems. Soil water content and soil water repellency recorded higher values in the IAOs, but no significant differences were observed between the sites.

Table 1. Descriptive statistics, Levene's test, and *t*-test for soil characteristics.

Land Use Systems	**Intensive Almond Orchards (IAOs)**				**Extensive Olive Groves (EOGs)**				**Levene's Test for Equality of Variances**		***t*-Test for Equality of Means**	
	min.	mean	max.	SD	min.	mean	max.	SD	Z	Sig.	*t*	Sig. (2-tailed)
Slope (%)	2.0	19.2	39.0	12.4	3.0	10.3	17.0	3.9	6.31	**0.021**	2.361	**0.028**
Soil moisture (%)	1.4	5.1	10.0	2.8	1.2	4.3	6.0	1.5	1.498	0.235	−0.849	0.406
Water repellence	0.0	7.1	24.0	8.2	0.0	4.8	13.0	5.2	3.779	0.066	0.801	0.432
Resistance to penetration (g m^{-2})	2.5	3.9	4.5	0.6	1.5	3.6	4.5	1.2	9.772	**0.005**	−0.742	0.467
Bulk density (g cm^{-3})	1.1	1.3	1.5	0.1	0.9	1.1	1.6	0.2	4.924	**0.038**	1.538	0.140
Silt + clay (%)	3.8	10.9	26.2	8.1	6.6	30.5	59.2	20.2	7.45	**0.013**	−2.88	**0.009**
Sand (%)	46.9	61.5	89.4	15.6	12.6	39.9	67.4	17.3	0.076	0.786	3.062	**0.006**
Stoniness (%)	5.3	27.7	45.8	13.8	13.3	29.9	40.6	8.1	3.824	0.065	−0.461	0.650
Natural plant-residue mulch layer (%)	0.0	45.4	90.0	43.6	10.0	59.9	95.0	34.9	4.79	**0.045**	−0.662	0.449

Significance level tests are in bold.

Resistance to penetration, bulk density, and silt + clay registered significant differences when Levene's test for the equality of variance was applied, whilst sand percentages showed significant differences when the *t*-test was applied. In general, the IAOs recorded the highest mean value of bulk density (1.3 g cm^{-3} against 1.1 g cm^{-3} for the EOGs), resistance to penetration (3.9 g cm^{-2} vs. 3.6 g cm^{-2} for the EOGs), and percentage of sand (median of 61.5% versus 39.9% for the EOGs). Conversely, the mean percentage of silt + clay was higher for the EOGs than for the IAOs, with figures of 30.5% and 10.9%, respectively, showing significant differences when Levene's test was applied. The percentage of stoniness (27.7% and 29.9%, respectively, for IAOs and EOGs) was very similar in both land use systems.

Finally, plant cover showed significant differences between the land use systems, with the IAOs recording a mean of 45%, but with great variability between plots, ranging from no cover (0%) to 90% plant cover. In the EOGs, the mean value was around 60%, with a standard deviation of 34.9%.

3.2. Runoff and Soil Erosion Response

The mean time required for runoff initiation was very similar between the land use systems, varying between 45 s and 720 s (mean: 249 s) for the IAOs and from 135 s and 960 s (mean: 302 s) for the EOGs. No differences were found between runoff responses, which varied from 4.4 to 81.5% (mean: 43%) and 1.1 to 69.5% (mean: 41.6%) for IAOs and EOGs, respectively (Table 2 and Figure 4).

Table 2. Descriptive statistics, Levene's test, and *t*-test for runoff and soil erosion.

Land Use System	**Intensive Almond Orchards (IAOs)**				**Extensive Olive Groves (EOGs)**				**Levene's Test for Equality of Variances**		***t*-Test for Equality of Means**	
	min.	mean	max.	SD	min.	mean	max.	SD	Z	Sig.	t	Sig. (2-tailed)
Runoff initiation (s)	45	249	720	212	135	302	960	252	0.155	0.698	−0.506	0.619
Runoff coefficient (%)	4.4	43.0	81.5	31.8	1.1	41.6	69.5	22.2	2.953	0.101	0.121	0.905
Soil loss (g m^{-2} h^{-1})	1.6	118.0	440.0	156.5	1.0	12.2	37.6	11.2	36.964	**0.000**	2.347	**0.029**
Sediment concentration (g L^{-1})	0.3	3.1	10.3	3.6	0.1	0.7	1.8	0.6	26.921	**0.000**	2.33	**0.030**

Significance level tests are in bold.

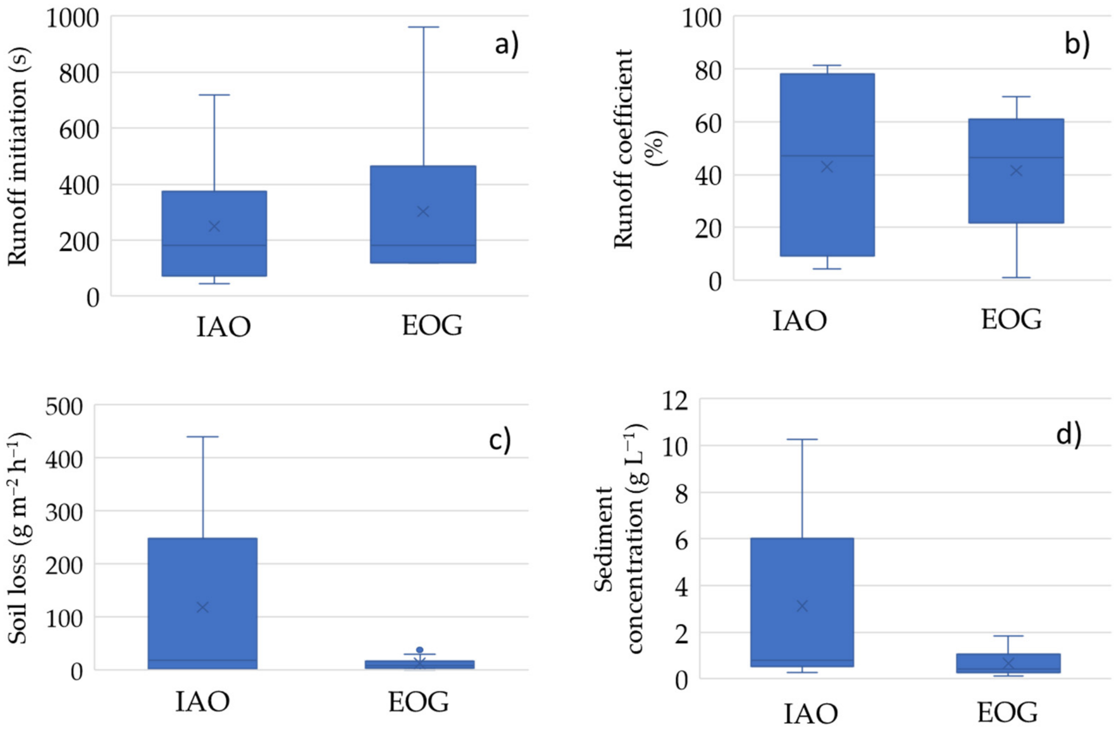

Figure 4. Comparative runoff initiation (**a**), runoff coefficient (**b**), soil loss (**c**), and sediment (**d**) concentration in the IAOs and EOGs.

Conversely, significant differences were found between median soil loss from the two land use systems. For IAO sites, the median value for soil loss was 118 g m^{-2} h^{-1}, while for EOG plots, it was 12.2 g m^{-2} h^{-1}. For the IAOs, the recorded values varied between 1 g m^{-2} h^{-1} and 440 g m^{-2} h^{-1} (SD: 156 g m^{-2} h^{-1}), whilst for the EOGs, the minimum and maximum values were 1 and 37.6 g m^{-2} h^{-1} (SD: 11.2 g m^{-2} h^{-1}).

Sediment concentration also registered a significant statistical difference when Levene's and *t*-tests were applied. For the IAOs, the median and maximum values were 3.1 and 10.3 g L^{-1} (SD: 3.6 g L^{-1}), whereas, for the EOG system, the recorded values ranged between 0.7 and 1.8 g L^{-1} (SD: 0.6 g L^{-1}).

3.3. Runoff and Soil Erosion Influencing Factors

To determine which variables had more influence on runoff and sediment loss, Spearman correlations were carried out (Table 3). The results show that runoff initiation was significantly and negatively correlated with slope (Rs: −0.450) and positively correlated with herbaceous or natural plant-residue mulch cover (Rs: 0.642). Slope also showed positive and significant correlations with runoff discharge (Rs: 0.439) and soil loss (Rs: 0.445).

Table 3. Spearman's rank correlation coefficients (Rs) for studied variables.

	Runoff Initiation (s)	**Runoff Coefficient (%)**	**Soil Loss ($g\ m^{-2}\ h^{-1}$)**	**Sediment Concentration ($g\ L^{-1}$)**
Slope	−0.450 *	0.439 *	0.445 *	0.101
Soil moisture	−0.047	0.088	−0.095	−0.075
Water repellency	−0.090	0.047	−0.263	−0.350
Resistance to penetration	0.054	−0.124	−0.024	−0.001
Bulk density	0.011	0.005	−0.288	−0.337
Silt + clay	0.032	0.039	0.028	−0.058
Sand	0.267	−0.379	0.442 *	−0.080
Stoniness	−0.258	0.374	−0.556 **	0.190
Natural plant-residue mulch layer	0.642 **	−0.633 **	−0.862 **	−0.639 **

Significance level notations are as follows: ** $p < 0.01$; * $p < 0.05$ (1-tailed).

Runoff discharge was also significantly and negatively correlated with soil cover (Rs: −0.633). Soil loss also demonstrated a significant negative correlation with vegetation cover (Rs: −0.862) and the percentage of stoniness (Rs: −0.556). Sandy soil showed a positive correlation with sediment yield (Rs: 0.442). The sediment concentration was significantly and negatively correlated with soil cover (Rs: −0.639). As runoff and soil erosion often occur in sequence, a significant correlation was observed between these variables (Rs: 0.757).

4. Discussion

Beira Baixa is very susceptible to desertification. In this region, long periods of drought, irregular precipitation, and intense storms, combined with unsustainable agricultural practices and low vegetation cover, can leave soils vulnerable to erosion and, therefore, hasten land degradation and encourage desertification. A better knowledge of the processes driving runoff and soil erosion under different land uses is a key issue in fostering a more sustainable land management system.

Longer rainstorms simulated in the two studied land use systems produced significant runoff flow and soil loss. Differences between paired IAOs and EOG plots show an evident impact of the intensive almond orchards on accelerating soil erosion risk compared with extensive traditional olive groves, although runoff initiation and discharge are very similar in the studied land uses. When mean values for soil loss and sediment concentration were compared, the results were 118 and 12 $g\ m^{-2}\ h^{-1}$ and 3.1 and 0.7 $g\ L^{-1}$, respectively, for IAOs and EOGs. These results confirm the widespread perceptions of negative environmental connotations linked to intensive orchards [79,80] related to substantial disturbances of the soil, large-scale mechanized development, and installation on steep terrain conditions. Furthermore, in many of them, the herbaceous under-cover has been removed, which leads to a greater risk of soil erosion [55,79,80].

Considering the factors controlling runoff coefficient and soil erosion, the dominant factors in the land use systems studied were slope, soil texture, and, especially, soil vegetation cover. In fact, the presence of a natural plant-residue mulch layer at the end of the summer significantly reduced runoff and soil erosion. Our results are, therefore, consistent with those of previous research developed in the field, in laboratory facilities, or obtained by modeling approaches, which demonstrate that soil vegetation cover is the key factor determining splash erosion and thus affects sediment delivery at the pedon scale [10,12,13,19,20,41,46,81–84].

In the study area, there was a clear contrast in soil loss between bare or less covered soils and plots with high percentages of herbaceous communities or natural plant-residue mulch layers in both land use systems (Figure 5). This difference was especially significant in the IAOs where vegetation control was based on the application of herbicides or mowing by using power tools or heavy machinery. In the areas where herbicide was applied, the soil was uncovered almost all year. Conversely, where mowing was applied to control vegetation between the rows, the soil cover was relatively high at the end of the summer.

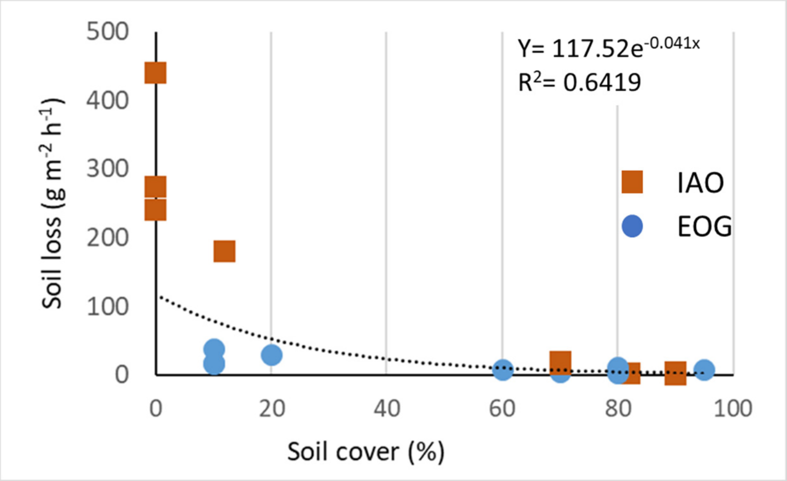

Figure 5. Correlation between soil cover and soil loss in the studied land use systems.

Consequently, for intensive soil use, the median value obtained at the end of the hot and dry summer for plots without any or with less than 10% of soil cover was around 280 g m^{-2} h^{-1}, in contrast to plots with more than 70% of soil cover, with an average of 8 g m^{-2} h^{-1}. For the EOGs, the values were 25 g m^{-2} h^{-1} and 5 g m^{-2} h^{-1} for plots with less than 10% and more than 70% of soil cover, respectively. These results, in line with other studies, confirm that maintaining vegetation cover is an important measure for the prevention and control of soil erosion, especially for IAOs, where enduring high percentages (>70%) of herbaceous or natural plant-residue mulch cover reduced soil loss by about 70%.

In this regard, the results obtained by Rodríguez Sousa et al. [63] in the Alentejo region also highlight that intensive olive groves with herbicide and vegetation stripe cover densities lower than 20% showed higher erosion rates, in contrast with highly intensive and organic groves, where the vegetation cover was higher than 50%, which showed a minimal impact of erosive processes, as well as extensive groves with 100% vegetation cover. Marques et al. [85] analyzed soil loss in an olive grove in central Spain and also found that when cover exceeds 60%, rainfall erosivity declines drastically, reducing soil erosion.

The way that vegetation cover is spatially distributed on slopes is an important factor in decreasing runoff and sediment transport [86,87]. In the study area, retaining high percentages of soil cover was especially relevant on the highest slopes, and it was also a variable that helped to foster higher runoff (Rs: 0.439) and soil erosion (0.445). Several authors (64, 101–104) note that slopes play an important role in impacting runoff and soil erosion intensity, finding that whilst infiltration decreases, runoff velocity and soil splash detachment increase with increasing slope gradient. For example, Durán Zuazo et al. [84] concluded that the conservation or cultivation of plants can help prevent runoff and soil erosion on steep slopes, thereby reconciling sustainable agricultural practice and environmental protection in a mountainous area of Spain.

On the other hand, the soils in the studied plots in both the IAOs and the traditional EOGs were poor in organic matter; thus, there is an urgent need to stop further degradation and restore soil quality and associated soil functions. A soil cover with a permanent natural plant-residue mulch layer is a natural product that enhances soil functions in the long term and has an immediate effect on soil erosion and, therefore, can be an option to achieve these goals [35]. Natural plant-residue mulch layers are also effective at boosting soil properties, enhancing biological activity, balancing the nitrogen cycle, and controlling temperature and water retention, among other benefits [87].

Deep plowing for the installation of almond orchards disturbs the soil, and the repeated passage of heavy machinery leads to soil compaction [26,88–90]. Several studies demonstrate that higher values of bulk density and soil compaction help to reduce soil infiltration and increase surface soil erosion [91,92]. Although higher bulk density and soil resistance to penetration were recorded in the IAO plots, we did not find a significant correlation between those variables and the hydrogeomorphic response of the soil. However, the development of microcrusts in some IAO plots stimulated runoff and thus sediment transport [93]. In general, soil erosion was positively associated with sandy soils, whilst stoniness was linked with lower mean values of sediment transport [94–97].

Although the results of this work indicate that the large-scale mechanized development of IAOs together with low vegetation cover on steep terrain leads to serious risks of soil erosion, more research is needed. In fact, one of the limitations of this work is the small number of rainfall simulations; these should be extended to include a larger number of plots and strengthen the results obtained in both land use systems. Moreover, at the hillslope scale, other processes such as rill and gully erosion and the impact of roads and manmade structures must be analyzed. These attributes can increase total erosion and accelerate sediment transport downstream or, conversely, large volumes of water and sediment can also be retained along the hillslope [98]. There is a need to understand how land management affects the connectivity of water and sediments along hillslopes.

Fieldwork allowed us to confirm that some farmers are increasingly aware of the need to maintain vegetation cover as a measure to mitigate runoff and soil erosion. In some cases, they have even started to implement techniques to manage vegetation cover throughout the year. In this case, the measures applied to soil management systems that greatly reduce on-site runoff and soil erosion and can also contribute to the improvement of soil quality need urgent evaluation since this region is seriously affected by severe land degradation and high susceptibility to desertification. This is an issue of special concern considering that the Mediterranean region has been declared a climate change hotspot for various reasons, but especially because an expected increase in torrential rains [99] will increase the potential for soil loss by erosion.

5. Conclusions

Soil conservation is one of the main environmental challenges regarding Mediterranean agricultural systems where soil erosion is a major environmental problem affecting both the sustainability of agroecosystems and their capacity to supply ecosystem services. Land use is clearly one of the most important determinants of soil erosion, and recent trends associated with the replacement of traditional extensive land uses by intensive farming might be exacerbating such problems. Based on the results obtained, it is possible to confirm that intensive almond orchards suffer from higher rates of soil erosion than extensive traditional olive groves do, mainly in low vegetation cover conditions. The increasing erosion rates are as much as ten times those measured in extensive olive groves, and sediment concentration is five times higher.

However, the maintenance of soil cover in IAOs, based on a natural plant-residue mulch layer or herbaceous cover, especially at the end of the summer, might be a suitable measure since it significantly reduces soil loss and sediment concentration. Our results demonstrated that under high-intensity rainfall events, a high percentage (>70%) of natural plant-residue mulch layer reduced soil loss by about 70% and reduced sediment concentration by 90%. In this context, it is crucial to establish significant ground cover in IAOs to reduce and control soil erosion with the aim of achieving the United Nations Goal 15, centered around stopping and reversing land degradation and combating desertification.

This study provides a useful suggestion for farmers that need to be convinced to implement a type of management based on soil conservation tillage during the year that preserves residue cover between intensive almond rows.

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References

1. García-Ruiz, J.M.; Beguería, S.; Nadal-Romero, E.; González-Hidalgo, J.C.; Lana-Renault, N.; Sanjuán, Y. A meta-analysis of soil erosion rates across the world. *Geomorphology* **2015**, *239*, 160–173. [CrossRef]
2. Amundson, R.; Berhe, A.A.; Hopmans, J.W.; Olson, C.; Sztein, A.E.; Sparks, D.L. Soil and human security in the 21st century. *Science* **2015**, *348*, 1261071. [CrossRef] [PubMed]
3. Fu, B.; Zhang, L.; Xu, Z.; Zhao, Y.; Wei, Y.; Skinner, D. Ecosystem services in changing land use. *J. Soils Sediments* **2015**, *15*, 833–843. [CrossRef]
4. Anache, J.A.; Wendland, E.C.; Oliveira, P.T.; Flanagan, D.C.; Nearing, M.A. Runoff and soil erosion plot-scale studies under natural rainfall: A meta-analysis of the Brazilian experience. *Catena* **2017**, *152*, 29–39. [CrossRef]
5. Keesstra, S.; Pereira, P.; Novara, A.; Brevik, E.C.; Azorin-Molina, C.; Parras-Alcántara, L.; Jordán, A.; Cerdà, A. Effects of soil management techniques on soil water erosion in apricot orchards. *Sci. Total. Environ.* **2016**, *551–552*, 357–366. [CrossRef]
6. Steffan, J.J.; Brevik, E.C.; Burgess, L.C.; Cerdà, A. The effect of soil on human health: An overview. *Eur. J. Soil Sci.* **2018**, *69*, 159–171. [CrossRef]
7. Gessesse, B.; Bewket, W.; Bräuning, A. Model-Based Characterization and Monitoring of Runoff and Soil Erosion in Response to Land Use/land Cover Changes in the Modjo Watershed, Ethiopia. *Land Degrad. Dev.* **2015**, *26*, 711–724. [CrossRef]
8. Karamesouti, M.; Detsis, V.; Kounalaki, A.; Vasiliou, P.; Salvati, L.; Kosmas, C. Land-use and land degradation processes affecting soil resources: Evidence from a traditional Mediterranean cropland (Greece). *Catena* **2015**, *132*, 45–55. [CrossRef]
9. Ligonja, P.J.; Shrestha, R.P. Soil Erosion Assessment in Kondoa Eroded Area in Tanzania using Universal Soil Loss Equation, Geographic Information Systems and Socioeconomic Approach. *Land Degrad. Dev.* **2015**, *26*, 367–379. [CrossRef]
10. Ochoa, P.; Fries, A.; Mejía, D.; Burneo, J.; Ruíz-Sinoga, J.; Cerdà, A. Effects of climate, land cover and topography on soil erosion risk in a semiarid basin of the Andes. *Catena* **2016**, *140*, 31–42. [CrossRef]
11. Panagos, P.; Borrelli, P.; Poesen, J.; Ballabio, C.; Lugato, E.; Meusburger, K.; Montanarella, L.; Alewell, C. The new assessment of soil loss by water erosion in Europe. *Environ. Sci. Policy* **2015**, *54*, 438–447. [CrossRef]
12. Sastre, B.; Barbero-Sierra, C.; Bienes, R.; Marques, M.J.; García-Díaz, A. Soil loss in an olive grove in Central Spain under cover crops and tillage treatments, and farmer perceptions. *J. Soils Sediments* **2017**, *17*, 873–888. [CrossRef]
13. Nadal-Romero, E.; Petrlic, K.; Verachtert, E.; Bochet, E.; Poesen, J. Effects of slope angle and aspect on plant cover and species richness in a humid Mediterranean badland: Topography-induced patterns of vegetation in a humid badland area. *Earth Surf. Process. Landforms* **2014**, *39*, 1705–1716. [CrossRef]
14. Kinnell, P.I.A. The impact of slope length on the discharge of sediment by rain impact induced saltation and suspension. *Earth Surf. Process. Landforms* **2009**, *34*, 1393–1407. [CrossRef]
15. Cerdà, A. Parent Material and Vegetation Affect Soil Erosion in Eastern Spain. *Soil Sci. Soc. Am. J.* **1999**, *63*, 362–368. [CrossRef]
16. Sinoga, J.R.; Murillo, J.M. Hydrological response of abandoned agricultural soils along a climatological gradient on metamorphic parent material in southern Spain. *Earth Surf. Process. Landforms* **2009**, *34*, 2047–2056. [CrossRef]
17. Martínez-Hernández, C.; Rodrigo-Comino, J.; Romero-Díaz, A. Impact of lithology and soil properties on abandoned dryland terraces during the early stages of soil erosion by water in south-east Spain. *Hydrol. Process.* **2017**, *31*, 3095–3109. [CrossRef]
18. Bughici, T.; Wallach, R. Formation of soil–water repellency in olive orchards and its influence on infiltration pattern. *Geoderma* **2016**, *262*, 1–11. [CrossRef]
19. Nunes, A.N.; Coelho, C.O.A.; de Almeida, A.C.; Figueiredo, A. Soil erosion and hydrological response to land abandonment in a central inland area of Portugal. *Land Degrad. Dev.* **2010**, *21*, 260–273. [CrossRef]
20. Nunes, A.N.; de Almeida, A.C.; Coelho, C.O.A. Impacts of land use and cover type on runoff and soil erosion in a marginal area of Portugal. *Appl. Geogr.* **2011**, *31*, 687–699. [CrossRef]

21. García-Ruiz, J.M.; Nadal-Romero, E.; Lana-Renault, N.; Beguería, S. Erosion in Mediterranean landscapes: Changes and future challenges. *Geomorphology* **2013**, *198*, 20–36. [CrossRef]
22. Wei, W.; Chen, L.; Fu, B.; Huang, Z.; Wu, D.; Gui, L. The effect of land uses and rainfall regimes on runoff and soil erosion in the semi-arid loess hilly area, China. *J. Hydrol.* **2007**, *335*, 247–258. [CrossRef]
23. Yue, L.; Juying, J.; Bingzhe, T.; Binting, C.; Hang, L. Response of runoff and soil erosion to erosive rainstorm events and vegetation restoration on abandoned slope farmland in the Loess Plateau region, China. *J. Hydrol.* **2020**, *584*, 124694. [CrossRef]
24. Cerdà, A.; Rodrigo-Comino, J.; Giménez-Morera, A.; Keesstra, S.D. An economic, perception and biophysical approach to the use of oat straw as mulch in Mediterranean rainfed agriculture land. *Ecol. Eng.* **2017**, *108*, 162–171. [CrossRef]
25. Comino, J.R.; Senciales, J.; Ramos, M.; Martínez-Casasnovas, J.; Lasanta, T.; Brevik, E.; Ries, J.; Sinoga, J.R. Understanding soil erosion processes in Mediterranean sloping vineyards (Montes de Málaga, Spain). *Geoderma* **2017**, *296*, 47–59. [CrossRef]
26. Bogunovic, I.; Trevisani, S.; Seput, M.; Juzbasic, D.; Durdevic, B. Short-range and regional spatial variability of soil chemical properties in an agro-ecosystem in eastern Croatia. *Catena* **2017**, *154*, 50–62. [CrossRef]
27. Martínez-Mena, M.; López, J.; Almagro, M.; Albaladejo, J.; Castillo, V.; Ortiz, R.; Boix-Fayos, C. Organic carbon enrichment in sediments: Effects of rainfall characteristics under different land uses in a Mediterranean area. *Catena* **2012**, *94*, 36–42. [CrossRef]
28. Taguas, E.; Ayuso, J.; Pérez, R.; Giráldez, J.; Gómez, J. Intra and inter-annual variability of runoff and sediment yield of an olive micro-catchment with soil protection by natural ground cover in Southern Spain. *Geoderma* **2013**, *206*, 49–62. [CrossRef]
29. Yu, Y.; Wei, W.; Chen, L.; Feng, T.; Daryanto, S. Quantifying the effects of precipitation, vegetation, and land preparation techniques on runoff and soil erosion in a Loess watershed of China. *Sci. Total. Environ.* **2019**, *652*, 755–764. [CrossRef]
30. Gyssels, G.; Poesen, J.; Bochet, E.; Li, Y. Impact of plant roots on the resistance of soils to erosion by water: A review. *Prog. Phys. Geogr.* **2005**, *29*, 189–217. [CrossRef]
31. Zhang, S.; Yang, H.; Yang, D.; Jayawardena, A.W. Quantifying the effect of vegetation change on the regional water balance within the Budyko framework. *Geophys. Res. Lett.* **2016**, *43*, 1140–1148. [CrossRef]
32. Teng, H.; Liang, Z.; Chen, S.; Liu, Y.; Rossel, R.A.V.; Chappell, A.; Yu, W.; Shi, Z. Current and future assessments of soil erosion by water on the Tibetan Plateau based on RUSLE and CMIP5 climate models. *Sci. Total. Environ.* **2018**, *635*, 673–686. [CrossRef]
33. Chalise, D.; Kumar, L.; Kristiansen, P. Land Degradation by Soil Erosion in Nepal: A Review. *Soil Syst.* **2019**, *3*, 12. [CrossRef]
34. García-Ruiz, J.M.; Beguería, S.; Lanarenault, N.; Nadal-Romero, E.; Cerdà, A. Ongoing and Emerging Questions in Water Erosion Studies. *Land Degrad. Dev.* **2017**, *28*, 5–21. [CrossRef]
35. Keesstra, S.; Rodrigo-Comino, J.; Novara, A.; Giménez-Morera, A.; Pulido, M.; Di Prima, S.; Cerdà, A. Straw mulch as a sustainable solution to decrease runoff and erosion in glyphosate-treated clementine plantations in Eastern Spain. An assessment using rainfall simulation experiments. *Catena* **2019**, *174*, 95–103. [CrossRef]
36. Novara, A.; Stallone, G.; Cerdà, A.; Gristina, L. The Effect of Shallow Tillage on Soil Erosion in a Semi-Arid Vineyard. *Agronomy* **2019**, *9*, 257. [CrossRef]
37. Riva, M.J.; Daliakopoulos, I.N.; Eckert, S.; Hodel, E.; Liniger, H. Assessment of land degradation in Mediterranean forests and grazing lands using a landscape unit approach and the normalized difference vegetation index. *Appl. Geogr.* **2017**, *86*, 8–21. [CrossRef]
38. Briassoulis, H. Combating Land Degradation and Desertification: The Land-Use Planning Quandary. *Land* **2019**, *8*, 27. [CrossRef]
39. Ferreira, C.S.; Seifollahi-Aghmiuni, S.; Destouni, G.; Ghajarnia, N.; Kalantari, Z. Soil degradation in the European Mediterranean region: Processes, status and consequences. *Sci. Total. Environ.* **2022**, *805*, 150106. [CrossRef]
40. Borrelli, P.; Robinson, D.A.; Fleischer, L.R.; Lugato, E.; Ballabio, C.; Alewell, C.; Meusburger, K.; Modugno, S.; Schütt, B.; Ferro, V.; et al. An assessment of the global impact of 21st century land use change on soil erosion. *Nat. Commun.* **2017**, *8*, 2013. [CrossRef]
41. Panagos, P.; Borrelli, P.; Meusburger, K.; Alewell, C.; Lugato, E.; Montanarella, L. Estimating the soil erosion cover-management factor at the European scale. *Land Use Policy* **2015**, *48*, 38–50. [CrossRef]
42. Roxo, M.J. A Ação Antrópica No Processo de Degradação de Solo. A Serra de Mértola. Ph.D. Thesis, Faculdade de Ciências Sociais e Humanas, Universidade Nova de Lisboa, Lisboa, Portugal, 1994.
43. Cerdà, A.; Novara, A.; Moradi, E. Long-term non-sustainable soil erosion rates and soil compaction in drip-irrigated citrus plantation in Eastern Iberian Peninsula. *Sci. Total. Environ.* **2021**, *787*, 147549. [CrossRef]
44. Jie, C.; Jing-Zhang, C.; Man-Zhi, T.; Zi-Tong, G. Soil degradation: A global problem endangering sustainable development. *J. Geogr. Sci.* **2002**, *12*, 243–252. [CrossRef]
45. Atucha, A.; Merwin, I.A.; Brown, M.G.; Gardiazabal, F.; Mena, F.; Adriazola, C.; Lehmann, J. Soil erosion, runoff and nutrient losses in an avocado (Persea americana Mill) hillside orchard under different groundcover management systems. *Plant Soil* **2013**, *368*, 393–406. [CrossRef]
46. Gómez, J.; Battany, M.; Renschler, C.; Fereres, E. Evaluating the impact of soil management on soil loss in olive orchards. *Soil Use Manag.* **2003**, *19*, 127–134. [CrossRef]
47. Gómez, J.A.; Infante-Amate, J.; González De Molina, M.; Vanwalleghem, T.; Taguas, E.V.; Lorite, I. Olive Cultivation, its Impact on Soil Erosion and its Progression into Yield Impacts in Southern Spain in the Past as a Key to a Future of Increasing Climate Uncertainty. *Agriculture* **2014**, *4*, 170–198. [CrossRef]
48. Vanwalleghem, T.; Amate, J.I.; de Molina, M.G.; Fernández, D.S.; Gómez, J.A. Quantifying the effect of historical soil management on soil erosion rates in Mediterranean olive orchards. *Agric. Ecosyst. Environ.* **2011**, *142*, 341–351. [CrossRef]

49. Ibáñez, J.; Martínez-Valderrama, J.; Taguas, E.V.; Gómez, J.A. Long-term implications of water erosion in olive-growing areas in southern Spain arising from a model-based integrated assessment at hillside scale. *Agric. Syst.* **2014**, *127*, 70–80. [CrossRef]
50. Kairis, O.; Karavitis, C.; Kounalaki, A.; Salvati, L.; Kosmas, C. The effect of land management practices on soil erosion and land desertification in an olive grove. *Soil Use Manag.* **2013**, *29*, 597–606. [CrossRef]
51. Taguas, E.V.; Gómez, J.A. Vulnerability of olive orchards under the current CAP (Common Agricultural Policy) regulations on soil erosion: A study case in Southern Spain. *Land Use Policy* **2015**, *42*, 683–694. [CrossRef]
52. Cerdà, A.; Morera, A.G.; Bodí, M.B. Soil and water losses from new citrus orchards growing on sloped soils in the western Mediterranean basin. *Earth Surf. Process. Landforms* **2009**, *34*, 1822–1830. [CrossRef]
53. Li, X.H.; Yang, J.; Zhao, C.Y.; Wang, B. Runoff and Sediment from Orchard Terraces in Southeastern China: Soil Loss from Orchard Terraces. *Land Degrad. Dev.* **2014**, *25*, 184–192. [CrossRef]
54. Novara, A.; Gristina, L.; Guaitoli, F.; Santoro, A.; Cerdà, A. Managing soil nitrate with cover crops and buffer strips in Sicilian vineyards. *Solid Earth* **2013**, *4*, 255–262. [CrossRef]
55. Cerdà, A.; Rodrigo-Comino, J. Is the hillslope position relevant for runoff and soil loss activation under high rainfall conditions in vineyards? *Ecohydrol. Hydrobiol.* **2020**, *20*, 59–72. [CrossRef]
56. Prosdocimi, M.; Jordán, A.; Tarolli, P.; Keesstra, S.; Novara, A.; Cerdà, A. The immediate effectiveness of barley straw mulch in reducing soil erodibility and surface runoff generation in Mediterranean vineyards. *Sci. Total. Environ.* **2016**, *547*, 323–330. [CrossRef]
57. Faulkner, H. Gully erosion associated with the expansion of unterraced almond cultivation in the coastal Sierra de Lujar, S. Spain. *Land Degrad. Dev.* **1995**, *6*, 179–200. [CrossRef]
58. Doni, S.; Macci, C.; Peruzzi, E.; Masciandaro, G.; Ceccanti, B.; Mennone, C.; Garcia, C.; Hernandez, M.T.; Moreno-Ortega, J.L. Almond tree and land management practices for soil erosion protection in mediterranean areas. Spain. In Proceedings of the Third International Meeting on Environmental Biotechnology and Engineering, Palma de Mallorca, Spain, 21–25 September 2008.
59. Cerdà, A.; González-Pelayo, Ó.; Giménez-Morera, A.; Jordán, A.; Pereira, P.; Novara, A.; Brevik, E.C.; Prosdocimi, M.; Mahmoodabadi, M.; Keesstra, S.; et al. Use of barley straw residues to avoid high erosion and runoff rates on persimmon plantations in Eastern Spain under low frequency–high magnitude simulated rainfall events. *Soil Res.* **2016**, *54*, 154–165. [CrossRef]
60. Abrisqueta, J.; Plana, V.; Mounzer, O.; Mendez, J.; Ruiz-Sánchez, M. Effects of soil tillage on runoff generation in a Mediterranean apricot orchard. *Agric. Water Manag.* **2007**, *93*, 11–18. [CrossRef]
61. Jianjun, W.; Quansheng, L.; Lijiao, Y. Effect of Intercropping on Soil Erosion in Young Citrus Plantation—A Simulation Study. Chin. *J. Appl. Ecol.* **2017**, *8*, 143–146.
62. Guerrero-Casado, J.; Carpio, A.J.; Tortosa, F.S.; Villanueva, A.J. Environmental challenges of intensive woody crops: The case of super high-density olive groves. *Sci. Total. Environ.* **2021**, *798*, 149212. [CrossRef]
63. Sousa, A.A.R.; Muñoz-Rojas, J.; Brígido, C.; Prats, S.A. Impacts of agricultural intensification on soil erosion and sustainability of olive groves in Alentejo (Portugal). *Landsc. Ecol.* **2023**. [CrossRef]
64. García-Díaz, A.; Bienes, R.; Sastre, B.; Novara, A.; Gristina, L.; Cerdà, A. Nitrogen losses in vineyards under different types of soil groundcover. A field runoff simulator approach in central Spain. *Agric. Ecosyst. Environ.* **2017**, *236*, 256–267. [CrossRef]
65. Rodrigo-Comino, J. Five decades of soil erosion research in "terroir". The State-of-the-Art. *Earth-Science Rev.* **2018**, *179*, 436–447. [CrossRef]
66. Blavet, D.; De Noni, G.; Le Bissonnais, Y.; Leonard, M.; Maillo, L.; Laurent, J.; Asseline, J.; Leprun, J.; Arshad, M.; Roose, E. Effect of land use and management on the early stages of soil water erosion in French Mediterranean vineyards. *Soil Tillage Res.* **2009**, *106*, 124–136. [CrossRef]
67. Rosário, L. *Indicadores de Desertificação Para Portugal Continental. Lisboa: Direcção-Geral Dos Recursos Florestais*; Direcção-Geral dos Recursos Florestais: Lisboa, Portugal, 2004; p. 56.
68. FAO-UNESCO. Soil Map of the World. 1974. Available online: https://www.fao.org/3/as354e/as354e.pdf (accessed on 8 August 2023).
69. Renard, K.G.; Foster, G.R.; Weesies, G.A.; Porter, J.P. RUSLE: Revised Universal Soil Loss Equation. *J. Soil Water Conserv.* **1991**, *46*, 30–33.
70. Serviço de Reconhecimento e Ordenamento Agrário (SROA). *A Utilização Do Solo Em Portugal Continental*; Secretaria de Estado da Agricultura: Lisboa, Portugal, 1970.
71. Branco, D. Evolução do uso do solo na bacia do rio Pônsul nos últimos 60 anos: Estudo de caso do perímetro hidroagrícola de Idanha (Beira Baixa). Master's Thesis, University of Coimbra, Coimbra, Portugal, 2022.
72. Gonçalves, J.P. Mudanças no uso do solo na Bio-Região da Idanha: Avaliação da resposta hidrológica e erosiva dos solos. Master's Thesis, University of Coimbra, Coimbra, Portugal, 2023.
73. Cerdà, A.; Ibáñez, S.; Calvo, A. Design and operation of a small and portable rainfall simulator for rugged terrain. *Soil Technol.* **1997**, *11*, 163–170. [CrossRef]
74. Doerr, S.H. On Standardizing the 'Water Drop Penetration Time' and the 'Molarity of an Ethanol Droplet' Techniques to Classify Soil Hydrophobicity: A Case Study Using Medium Textured Soils. *Earth Surf. Process. Landf.* **1998**, *23*, 663–668. [CrossRef]
75. Tinsley, J. Determination of Organic Carbon in Soils by Dichromate Mixtures. In *Transactions 4th International Congress of Soil Science*; Hoitsemo Brothers: Gronigen, The Netherlands; Volume 1, pp. 161–169.
76. Brown, M.B.; Forsythe, A.B. Robust Tests for the Equality of Variances. *J. Am. Stat. Assoc.* **1974**, *69*, 364–367. [CrossRef]

77. Gastwirth, J.L.; Gel, Y.R.; Miao, W. The Impact of Levene's Test of Equality of Variances on Statistical Theory and Practice. *Stat. Sci.* **2009**, *24*, 343–360. [CrossRef]
78. Bautista-Capetillo, C.; Márquez-Villagrana, H.; Pacheco-Guerrero, A.; González-Trinidad, J.; Júnez-Ferreira, H.; Zavala-Trejo, M. Cropping System Diversification: Water Consumption against Crop Production. *Sustainability* **2018**, *10*, 2164. [CrossRef]
79. Caraveli, H. A comparative analysis on intensification and extensification in mediterranean agriculture: Dilemmas for LFAs policy. *J. Rural. Stud.* **2000**, *16*, 231–242. [CrossRef]
80. Rodrigo-Comino, J.; Taguas, E.; Seeger, M.; Ries, J.B. Quantification of soil and water losses in an extensive olive orchard catchment in Southern Spain. *J. Hydrol.* **2018**, *556*, 749–758. [CrossRef]
81. Niu, Y.; Li, X.; Wang, H.; Liu, Y.; Shi, Z.; Wang, L. Soil erosion-related transport of neonicotinoids in new citrus orchards. *Agric. Ecosyst. Environ.* **2020**, *290*, 106776. [CrossRef]
82. Angulo-Martínez, M.; Beguería, S.; Navas, A.; Machín, J. Splash erosion under natural rainfall on three soil types in NE Spain. *Geomorphology* **2012**, *175–176*, 38–44. [CrossRef]
83. Zuazo, V.H.D.; Martínez, J.R.F.; Pleguezuelo, C.R.R.; Raya, A.M.; Rodríguez, B.C. Soil-erosion and runoff prevention by plant covers in a mountainous area (se spain): Implications for sustainable agriculture. *Environmentalist* **2006**, *26*, 309–319. [CrossRef]
84. Durán-Zuazo, V.H.; Francia-Martínez, J.R.; García-Tejero, I.; Tavira, S.C. Implications of land-cover types for soil erosion on semiarid mountain slopes: Towards sustainable land use in problematic landscapes. *Acta Ecol. Sin.* **2013**, *33*, 272–281. [CrossRef]
85. Marques, M.J.; Bienes, R.; Pérez-Rodríguez, R.; Jiménez, L. Soil degradation in central Spain due to sheet water erosion by low-intensity rainfall events. *Earth Surf. Process. Landf.* **2008**, *33*, 414–423. [CrossRef]
86. Koulouri, M.; Giourga, C. Land abandonment and slope gradient as key factors of soil erosion in Mediterranean terraced lands. *Catena* **2007**, *69*, 274–281. [CrossRef]
87. Rodríguez, B.C.; Zuazo, V.H.D.; Galán, J.F.H.; Lipan, L.; Soriano, M.; Hernández, F.; Sendra, E.; Carbonell-Barrachina, Á.A.; Ruiz, B.G.; García-Tejero, I.F. Soil Management Strategies in Organic Almond Orchards: Implications for Soil Rehabilitation and Nut Quality. *Agronomy* **2023**, *13*, 749. [CrossRef]
88. Fullen, M.A. Compaction, hydrological processes and soil erosion on loamy sands in east Shropshire, England. *Soil Tillage Res.* **1985**, *6*, 17–29. [CrossRef]
89. Botta, G.; Rivero, D.; Tourn, M.; Melcon, F.B.; Pozzolo, O.; Nardon, G.; Balbuena, R.; Becerra, A.T.; Rosatto, H.; Stadler, S. Soil compaction produced by tractor with radial and cross-ply tyres in two tillage regimes. *Soil Tillage Res.* **2008**, *101*, 44–51. [CrossRef]
90. Becerra, A.T.; Botta, G.; Bravo, X.L.; Tourn, M.; Melcon, F.B.; Vazquez, J.; Rivero, D.; Linares, P.; Nardon, G. Soil compaction distribution under tractor traffic in almond (Prunus amigdalus L.) orchard in Almería España. *Soil Tillage Res.* **2010**, *107*, 49–56. [CrossRef]
91. Liu, Y.; Fu, B.; Lü, Y.; Wang, Z.; Gao, G. Hydrological responses and soil erosion potential of abandoned cropland in the Loess Plateau, China. *Geomorphology* **2012**, *138*, 404–414. [CrossRef]
92. Gregory, A.S.; Ritz, K.; McGrath, S.P.; Quinton, J.N.; Goulding, K.W.T.; Jones, R.J.A.; Harris, J.A.; Bol, R.; Wallace, P.; Pilgrim, E.S.; et al. A review of the impacts of degradation threats on soil properties in the UK. *Soil Use Manag.* **2015**, *31*, 1–15. [CrossRef]
93. Dan, C.; Liu, G.; Zhao, Y.; Shu, C.; Shen, E.; Liu, C.; Tan, Q.; Zhang, Q.; Guo, Z.; Zhang, Y. The effects of typical grass cover combined with biocrusts on slope hydrology and soil erosion during rainstorms on the Loess Plateau of China: An experimental study. *Hydrol. Process.* **2023**, *37*, e14794. [CrossRef]
94. Poesen, J.; Lavee, H. Rock fragments in top soils: Significance and processes. *Catena* **1994**, *23*, 1–28. [CrossRef]
95. Rubio, J.L.; Recatalá, L. The Relevance and Consequences of Mediterranean Desertification Including Security Aspects. In *Desertification in the Mediterranean Region. A Security Issue*; Kepner, W.G., Rubio, J.L., Mouat, D.A., Pedrazzini, F., Eds.; NATO Security Through Science Series; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2006; Volume 3, pp. 133–165. [CrossRef]
96. Martínez-Zavala, L.; Jordán, A. Effect of rock fragment cover on interrill soil erosion from bare soils in Western Andalusia, Spain. *Soil Use Manag.* **2008**, *24*, 108–117. [CrossRef]
97. Zavala, L.M.; Jordán, A.; Bellinfante, N.; Gil, J. Relationships between rock fragment cover and soil hydrological response in a Mediterranean environment. *Soil Sci. Plant Nutr.* **2010**, *56*, 95–104. [CrossRef]
98. Baartman, J.E.M.; Masselink, R.; Keesstra, S.D.; Temme, A.J.A.M. Linking landscape morphological complexity and sediment connectivity. *Earth Surf. Process. Landforms* **2013**, *38*, 1457–1471. [CrossRef]
99. Insua-Costa, D.; Senande-Rivera, M.; Llasat, M.C.; Miguez-Macho, G. A global perspective on western Mediterranean precipitation extremes. *npj Clim. Atmospheric Sci.* **2022**, *5*, 9. [CrossRef]