hydrology

MDPI

Article

Splash Erosion on Terraces, Does It Make a Difference If the Terracing Is Done before or after a Fire?

María Fernández-Raga [1,*], Martinho A. S. Martins [2], Elena Marcos Porras [3], Roberto Fraile [1] and Jan Jacob Keizer [2]

[1] Department of Chemistry and Applied Physics, University of León, 24071 León, Spain; rfral@unileon.es
[2] Centre for Environmental and Marine Studies (CESAM), Department of Environment, University of Aveiro, 3810-193 Aveiro, Portugal; martinho.martins@ua.pt (M.A.S.M.); jkeiset@dao.ua.pt (J.J.K.)
[3] Department of Biodiversity and Environmental Management, University of León, 24071 León, Spain; elena.marcos@unileon.es
* Correspondence: maria.raga@unileon.es

Abstract: Terraces are a common Mediterranean feature influencing soils, slopes and subsurface hydrology; however, little is known about their impact on erosion processes, especially in humid regions. The purpose of this study was to assess how terracing after a fire affected erosion processes such as splash erosion. For 8 months, the study monitored splash erosion in three terraced plots, one plot under pre-fire conditions and the other two under post-fire conditions. Assessment of the impact of the terracing treatment in such plots was carried out by the installation of two different splash erosion quantitative systems: cups and funnels. An analysis of the splash data obtained in 17 rainfall events and meteorological data collected during each one of those periods was then performed. A significant positive correlation between the amount of rainfall and the splash erosion was observed. The two splash sampling systems show a high degree of concordance; however, the funnel-type model seems to be the most appropriate when it comes to preventing loss of splashed soil samples. The post-fire treatment with terracing leads to a smaller stability of surface soil aggregates, causing higher splash erosion rates. Sampling using the funnel system collects three times the amount of splashed soil than that collected by the cup system, although both systems correlate appropriately with the meteorological parameters.

Keywords: splash erosion; rainfall; terraces; funnels; cups

check for updates

Citation: Fernández-Raga, M.; Martins, M.A.S.; Marcos Porras, E.; Fraile, R.; Keizer, J.J. Splash Erosion on Terraces, Does It Make a Difference If the Terracing Is Done before or after a Fire? *Hydrology* **2021**, *8*, 180. https://doi.org/10.3390/hydrology8040180

Academic Editors: Rusu Teodor and Giorgio Baiamonte

Received: 22 October 2021
Accepted: 5 December 2021
Published: 8 December 2021

1. Introduction

Fires produce a wide range of impacts on the soil, depending on factors such as soil characteristics (moisture, organic matter content, etc.), fire intensity or duration [1]. Ferreira et al. (2009) found that soil erosion was associated with increased soil vulnerability to erosion [2], mainly due to changes in the physical properties of soil. These changes are directly related to the effect of fire on organic matter [1] and with the elimination of vegetation and litter during combustion, favoring the destabilization of aggregates and subsequent disintegration [3,4]. The stability of aggregates is one of the factors that most influence the susceptibility of soil to erosion [5,6], as well the loss of vegetation after the fire, which leads to bare soil, so raindrops can produce a sealing of soil pores, increasing runoff rates [7,8].

In addition to fire, erosion can be aggravated by the type of management that is carried out [9–11]. One of the most aggressive management techniques in northern Portugal is the shallow cutting, which is carried out quite extensively in the Iberian Peninsula, both in burned areas and in productive farms [12]. In addition to this, deep plowing with ripper and terracing are very common, sometimes recommended to avoid the problem of erosion and sometimes accused of contributing to soil degradation and soil loss [13]. Indeed, terracing has been one of the most widely used techniques in forest improvement for afforestation and reforestation [14], culturally implanted in the Iberian Peninsula [15] and other Mediterranean areas [16,17]. Terracing maintains a dual purpose: on the one hand it improves the soil conditions of depth and soil drainage [18], while on the other, it limits the runoff of the surface [19–22]. However, this technique involves the modification of many ecological and environmental factors, such as water storage, water purification, changes in aquifer recharge and changes in erosion rates [23–25].

Terracing produces the mechanized translocation of the soil, burying the surface soil layer and raising the regolith layer during the creation of the terraces and therefore, causes a considerable impact that has received little attention [26]. Furthermore, different studies carried out in Spain have shown the negative influence of terracing on the soil erosion [3,27–29] and there are doubts about its suitability in Mediterranean conditions [12,20]. Some authors have said that terraced land is not recommended due to its high impact on soil horizons and physiography, except when applied on skeletal, low-evolved soil or in areas with gradients of slope between 30% and 65% [30,31]. However, others have shown that the correct execution of a terraced land prevents the runoff, as it causes an increase of infiltration that favors edaphic evolution [32] and allows the settlement of introduced or natural vegetation [23,33]. However, at the same time, it cuts the natural channels and limits the mobility of the material through the slope [34]. Indeed the treatment of terracing is controversial and has both admirers and detractors, even among authors who defend that no clear decrease in sediment deposition occurs after the terracing process [31,35].

In the Iberian Peninsula, there are more than 80 studies on terraces, and despite being a traditional technique used to avoid the loss of agricultural soil, in the last 20 years, it has started to be considered as an erosion producer [36]. In the Mediterranean area, the mosaic of landscapes of terraces and abandoned agricultural lands would explain the enormous increase in both forest fires and splash erosion [9,37]. In the Atlantic zone, ploughing and terracing are common practices in degraded areas, or where a fire has occurred [38]. For this reason terracing is often a technique associated with fires [20]. However, the turning of the horizons is when terracing makes quantifying the fire effect difficult, since the most fire-damaged surface horizons are buried after terracing.

Terraced areas show greater vulnerability to initiating processes of erosion such as splash erosion [39,40]. There are about sixty papers on terracing, erosion and fire, half of them published in the last 10 years, but when the study refers specifically to the effect of terracing fired areas in splash erosion, the number decrease to two papers only [10,41], according to the Web of Science, published by Clarivate Analytics, with the first of them published in 2010. If we consider all the papers on splash erosion and terracing, removing the fire influence, there are twenty-two papers, which began doing studies where the splash erosion was one factor in terracing effects, using specific systems to measure the influence, such as splash cups [42] or the splash boxes [43]. In 2003, the first paper on terraces with several splash erosion devices was published [44], followed to date by several other authors [41,45]. Currently, the discussion has evolved to measures that avoid the use of terraces and prevent erosion by leaving the litter layer and an understory in crops and tree plantations, as strategies for a sustainable land use [8,46].

Nevertheless terracing is not the main factor that affects splash erosion. Indeed, the power of the drops which fall on the soil is equally important on the splash erosion problem because it may affect the soil condition [47]. The impact of the droplets not only modifies the soil surface characteristics [48], but also causes the separation and subsequent emission of particles from the soil matrix and the consequent redeposition that can occur towards close areas or the transport by runoff to more distant areas [49,50]. The stability of the aggregates of the soil surface greatly affects the separation, transport and deposition of the soil particles, that is, their erosionability [51,52]. This stability expressed as a mean weight diameter (MWD) can be a good measure of the energy that a raindrop will need to be able to detach particles from the soil surface, thus initiating the process called splash erosion [53].

Since the beginning of the study of splash erosion [54], there has been two main difficulties: firstly, it is very difficult to separate splash erosion from other erosive processes, and secondly, erosion depends on the soil and precipitation characteristics, which are very local [55]. As a result, it is difficult to extrapolate the results to areas that are far from where they have been studied [56] and only two field studies on splash erosion have been carried out comparing several places around the world [41,57]. One is the study of Zambom [57], which was done at two sites in Austria and one in the Czech Republic, representing only part of center Europe, and the other is that of Fernández-Raga [41], done at two sites in Spain and Portugal. Both of these studies were conducted without terraces not burned, so they have very different results from our proposal in this paper. It should be noted, however, that some authors have done comparative studies analyzing soils with different degrees of vulnerability [58,59]. Therefore, it is very important when looking at a splash study to search for previous studies of splash erosion data in the area, in order to determine its evolution. In the chosen studied area there were several splash studies, which placed the recorded values in a range 96–119 mg m^{-2} mm^{-1} for the zone that was burned a long time ago and 1248–1717 mg m^{-2} mm^{-1} for the zone recently burned [41,60].

The main aim of this paper was to assess the effect of terracing on splash erosion by comparing three recently burned areas, one that suffered a fire after having been previously terraced whereas two others were terraced after the fire. In addition, we will determine the effect of rainfall on splash erosion and compare two different methods of measuring splash erosion.

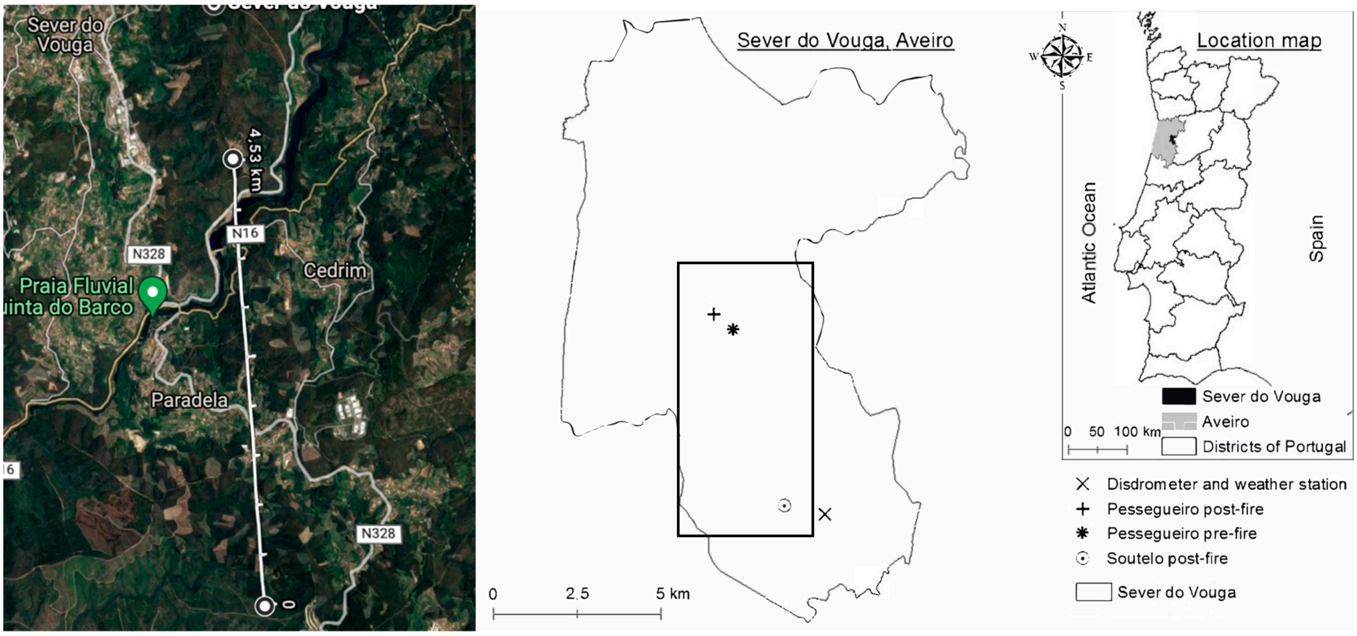
2. Materials and Methods

2.1. Study Site

The study area was located near the town of Soutelo, in the municipality of Sever do Vouga, in the north-central area of Aveiro, Portugal (Figure 1). The area is characterized by a humid meso-thermal climate, with warm and dry summers (Csb in the classification of Köppen). It is a climate totally influenced by the tempering effect of the Atlantic Ocean, in the form of strong winds and a humid air mass, producing intense rain with relative frequency. The average temperature at the nearest meteorological station, Campia, is 12.1 °C, and the monthly average varies between 6.2 °C for January and 19.3 °C for August [58]. The average annual rainfall is 1880 mm but it was much lower during the 2006–2007 hydrological year (1656 mm).

Three plots of *Eucalyptus globulus* were selected in this area called Soutelo, Pessegueiro I and Pessegueiro II, respectively, located with north exposure in Soutelo (40°40′43″ N and 8°20′48″ W) and south exposure in Pessegueiro (40°43′10″ N and 8°21′23″ W) and with an average slope of 30%. The three plots are separated by around 5 km of distance, with the same geology and at a height from 250 m to 320 m. The Soutelo area was burned in August 2006 and was terraced later in April 2007 (the slope is not mentioned as it is a terraced area). Pessegueiro I and II was burned in August 2007, but while Pessegueiro I was terraced in 2006 before the fire, Pessegueiro II was terraced post-fire in September 2007. In a first visual inspection of the Pessegueiro fires, no differences could be found between the severities. Some burnt litter and leaves were on the ground after the fire. Ashes were predominantly black (suggesting it was a moderate severity).

(**a**)



(**b**)

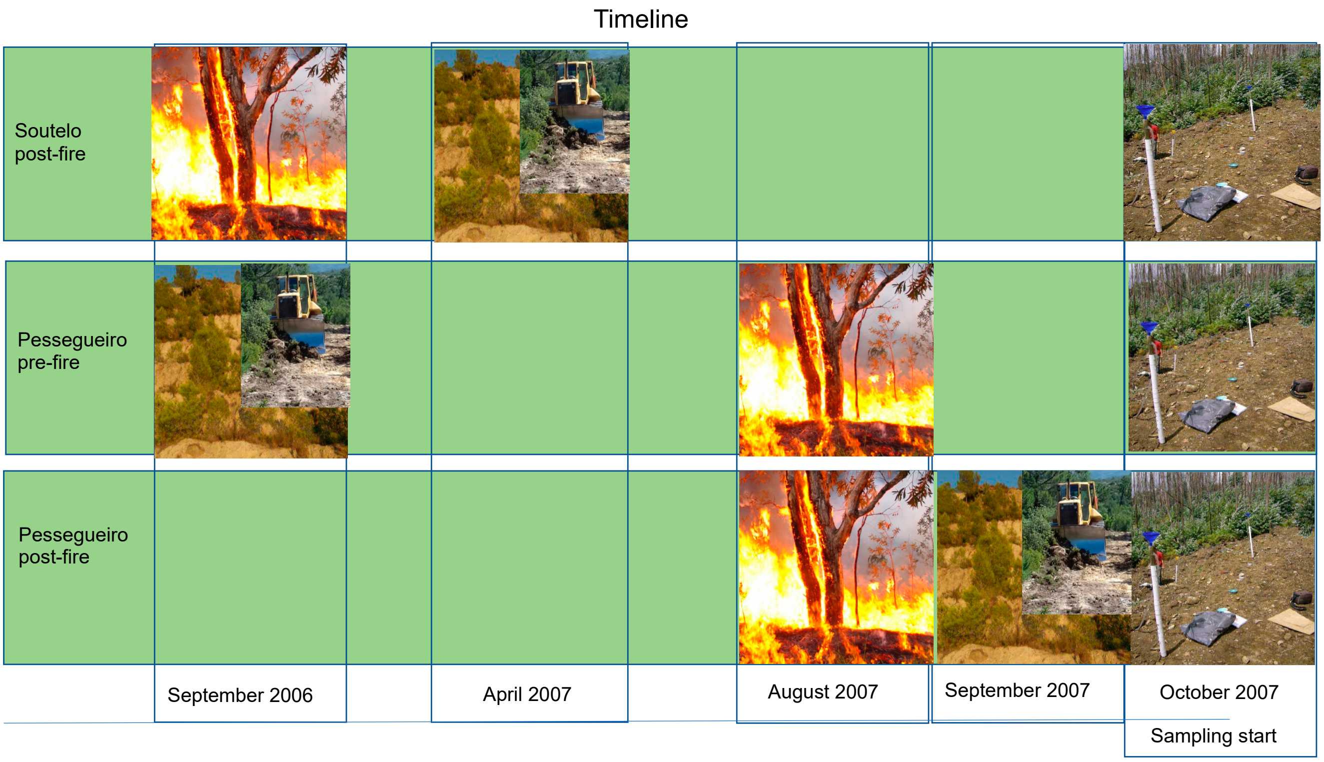


Figure 1. Study site in Soutelo and Pessegueiro, in North Portugal. (**a**) Location of disdrometer and pluviometer and sampling area of erosion. (**b**) Timeline of the fires and sampling period.

According to the existing soil map (1:1,000,000) [41,59,60], the soil in the study area is predominantly Humic Cambisols and Dystric Litosols developed on schists and granites [61]. Soil profiles were profoundly altered by the terracing carried out.

2.2. Experimental Design

Based on the bibliography, two splash erosion devices were selected because they were the most suitable for the area, as described in Fernández-Raga et al. [41,56]: funnels and cups. Both are relatively simple devices that are cheap and easy to make, install and monitor at frequent intervals (by substituting paper filters) [52,56]. In the case of the funnel model, its use in earlier studies in the region [60,61] was also a relevant argument.

In each study area, 5 consecutive terraces were selected, so the sampling area covered an area of 160 m^2 (8 m between devices on each terrace and a 20 m distance between the terraces in the direction of the slope). Therefore, a total of 20 collection devices were installed in each zone: 10 cups and 10 funnels, distributed between the 5 terraces, starting the installation from upslope. In each terrace, the two types of devices were placed in pairs, but the position of each pair of each type of device was selected at random. Each device was placed 2 m away from the next device (Figure 2), and the upper part of each cup or funnel was raised 3 cm from the surface. Control zones (devices set on plastic) were located on one side next to the studied plots at the central terrace of each sampling area. The surface of the soil was protected against point compression by walking over wooden boards. The paper filters were collected from the funnels and cups after each rainfall event, and later dried in an oven at 105 °C and weighed. Table 1 shows the 17 rainfall events. The design of the devices has been described in more detail in Fernández-Raga et al. [41].

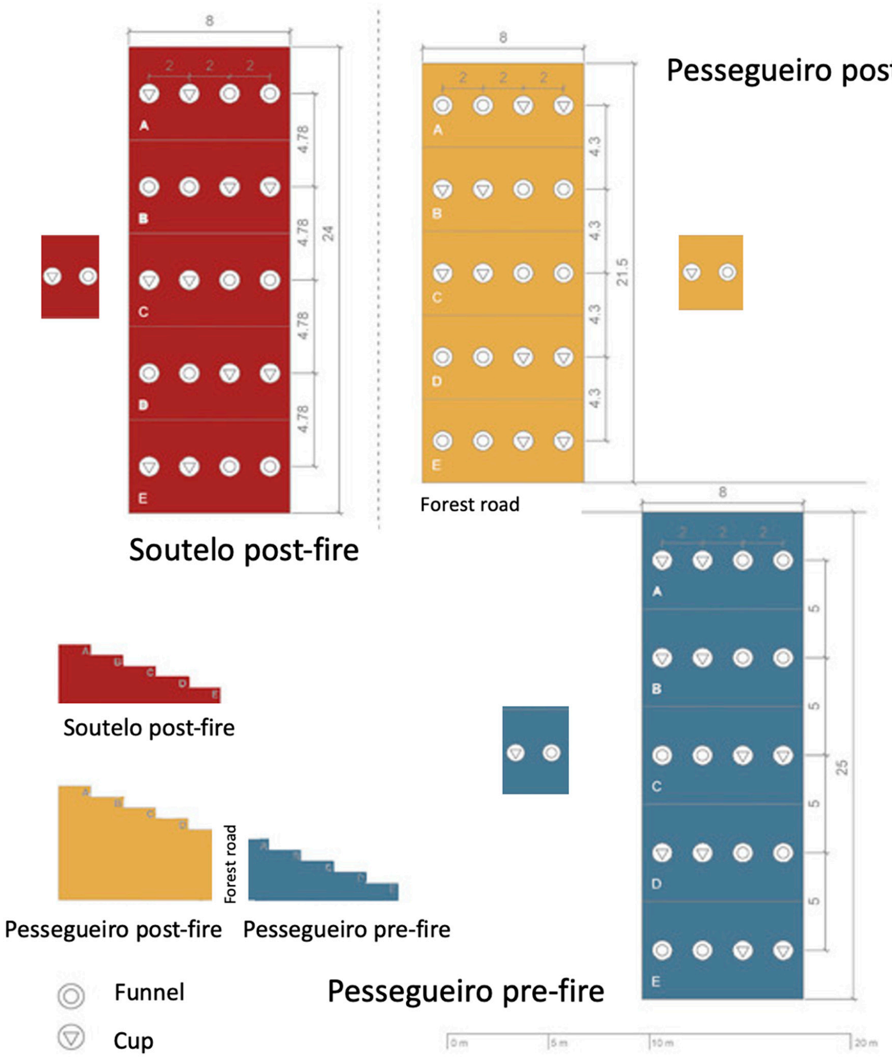


Figure 2. Experimental design for splash soil in Soutelo and Pessegueiro areas (all the units are in meters).

Table 1. Rainfall events of splash soil and precipitation in Soutelo and Pessegueiro.

Period	Start	End
1	4 October 2007	23 November 2007
2	23 November 2007	6 December 2007
3	6 December 2007	21 December 2007
4	21 December 2007	27 December 2007
5	27 December 2007	4 January 2008
6	4 January 2008	18 January 2008
7	18 January 2008	8 February 2008
8	8 February 2008	22 February 2008
9	22 February 2008	14 March 2008
10	14 March 2008	18 March 2008
11	18 March 2008	25 March 2008
12	25 March 2008	4 April 2008
13	4 April 2008	11 April 2008
14	11 April 2008	24 April 2008
15	24 April 2008	9 May 2008
16	9 May 2008	16 May 2008
17	16 May 2008	30 May 2008

2.3. Climatic Data

The rainfall data between 4 October 2007 and 30 May 2008 come from an automatic weather station called Davis Weather Link and several PRONAMIC automatic gauges. The Davis station was installed on the roof of a nearby building, located about 250 m from the Soutelo area and about 3.5 km from Pessegueiro. In addition, a total of seven rainfall gauges were sited in the study plots, one in Rosario, next to the disdrometer and the station, and the other six in pairs in Soutelo, Pessegueiro I or pre-fire and Pessegueiro II or post-fire. The rain gauges were always located one on the upper part of the terrace, and the other one on the lower part, to be able to study the variability between precipitations from one point to another. With the collected data, the maximum precipitation intensity was determined in 30 min (I_{30} in cm h^{-1}) following the indications described by several authors [62,63]. The total sampling period was divided into 17 periods, and the precipitation volume of each period is presented in Figure 3.

(**a**)

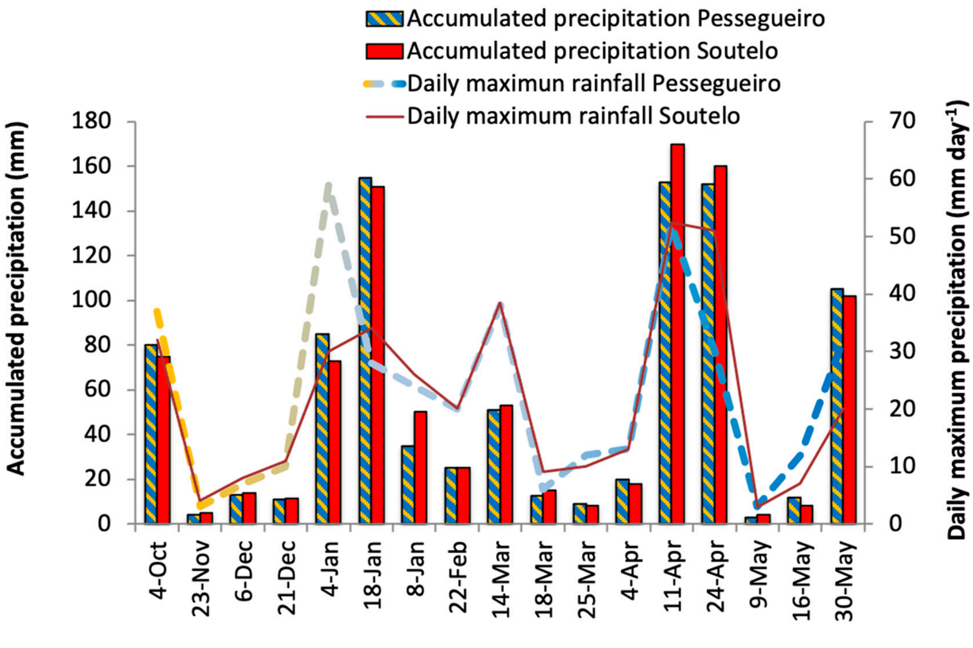


Figure 3. *Cont.*

(**b**)

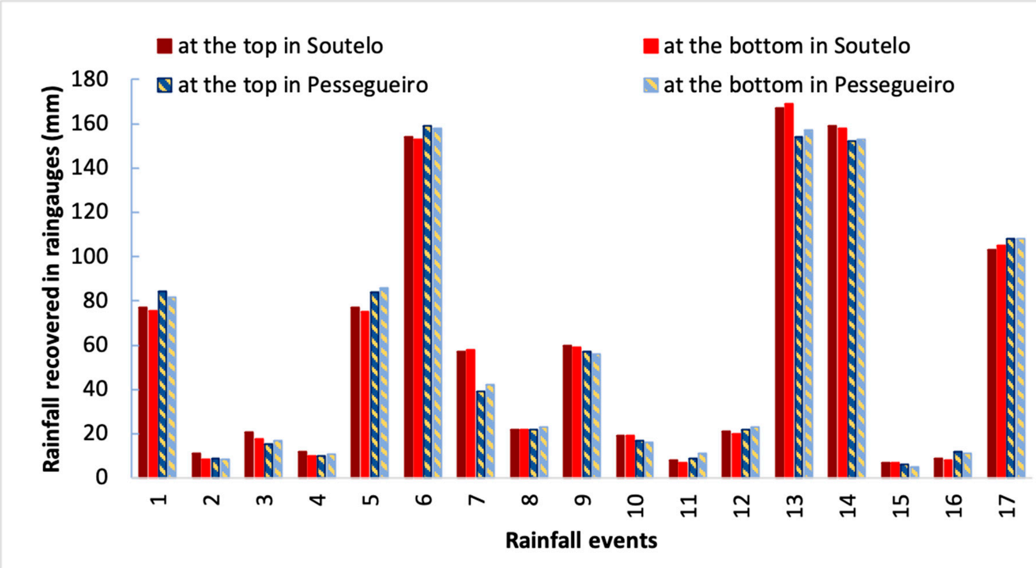


Figure 3. Rainfall data registered with the rain gauges in the areas: (**a**) accumulated precipitation and daily maximum precipitation (mm) registered in Pessegueiro and Soutelo during 17 rainfall events; (**b**) comparison between the mean rainfall per rain gauge situated in the areas of Pessegueiro (in yellow and blue) and Soutelo (in red) in the upper part of the terrace (darker colors) and at the bottom part (in light colors) in the 17 rainfall events.

2.4. Laboratory Analysis

Soil sample collection took place during an eight-month period, from 4 October 2007 to 30 May 2008. At each of the three study sites, ten soil samples were collected from the topsoil horizon (0–2 cm). To this end, the litter or ash layer was removed prior to sampling. The samples were air-dried and subsequently sieved with a mesh size of 10 mm.

Aggregate size distribution was determined by mechanically sieving the smaller-than-10 mm fractions through sieves of 5, 2, 1, 0.25 and 0.05 mm mesh size, and then weighing the resulting sub-fractions. Aggregate size distribution was then expressed as the dry mean weight diameter (MWD) following Kemper and Rosenau [64]. Particle size distribution was determined using the pipette method [65].

2.5. Data Analysis

Statistical analysis of the soil samples from the three areas, as well as the successive rain events during the sampling period, were carried out using the Wilcoxon non-parametric test [36], which allowed the comparison of the data before and after terracing treatment.

It is necessary to examine if the differences among the rainfall characteristics of the areas are statistically significant. In this study, we used the Wilcoxon signed-rank test to compare these data because the Wilcoxon test is non-parametric (distribution-free). To determine whether there were significative differences, we performed the one-tailed hypothesis test. The null hypothesis (H_0) was that "the two areas have the same rainfall characteristics". The alternative hypothesis (H_a) was that "the rainfall characteristics were different in Soutelo and in Pessegueiro". In the Wilcoxon test, we chose a significant level of 0.05. Then, the decision to reject the null hypothesis or not was based on the resulting *p*-value. If the *p*-value was greater than 0.05, it failed to reject the null hypothesis. Otherwise, if the *p*-value was less than 0.05, the null hypothesis was rejected at a confidence level of 95%. In this case, the Wilcoxon test was run using the software package SPSS 17.0, which was used for the statistical analyses, and testing was done against a significance level α of 0.05. We used again this test to determine if there were statistical differences in the aggregate sizes and in the soil type present in the experimental plots, with the null hypothesis (H_0) that "the two areas have the same quantity of splash erosion or aggregates sizes", and we again repeated the Wilcoxon test to analyze if the splash erosion recovered in each sample were different when terraced before and after the fire. In this last example, the null hypothesis was that "the splash erosion recovered from pre-fire areas are similar than the one recovered from post-fire terraces".

3. Results

3.1. Rain Characteristics

The maximum cumulative precipitation values exceeded 150 mm in both study areas during the spring in the periods 13 and 14, that is, from 4 to 11 and 11 to 24 April 2008 (Figure 3). The lowest accumulated rainfall values were less than 10 mm and corresponded with autumn from November 23 to December 6, and two spring periods, from 18 to 25 March and 24 April to 9 May 2008. In most of the periods, the precipitation registered in Soutelo was slightly higher than in Pessegueiro, although there were seven periods where this was reversed and more rain was recorded in Pessegueiro. However, when comparing the values of accumulated precipitation between the Pessegueiro and Soutelo zones using the Wilcoxon test [36], there were no significant differences ($p > 0.05$) between the two zones.

When comparing the maximum daily precipitation, there were two periods (from 27 December to 4 January, and from 16 to 30 May) in which Pessegueiro presented almost twice as much precipitation as Soutelo, reaching up to 60 mm (Figure 3). However, despite these two periods, no significant differences were found between the two study areas ($p > 0.05$).

Finally, the maximum intensity of precipitation in 30 min was compared (Figure 4). Again, in this case, the results of both areas were very similar, between 4 cm h^{-1} and 20 cm h^{-1}, except in period 13 (corresponding to 11 April), where the data from Soutelo was double the value of the data from Pessegueiro and reached 340 mm h^{-1}. There were seven periods in which the maximum intensity of Pessegueiro was slightly higher than that of Soutelo, and ten occasions when Soutelo reached a higher intensity of maximum precipitation in 30 min, but no significant differences were detected between both zones ($p > 0.05$) through the Wilcoxon test (Figure 3b).

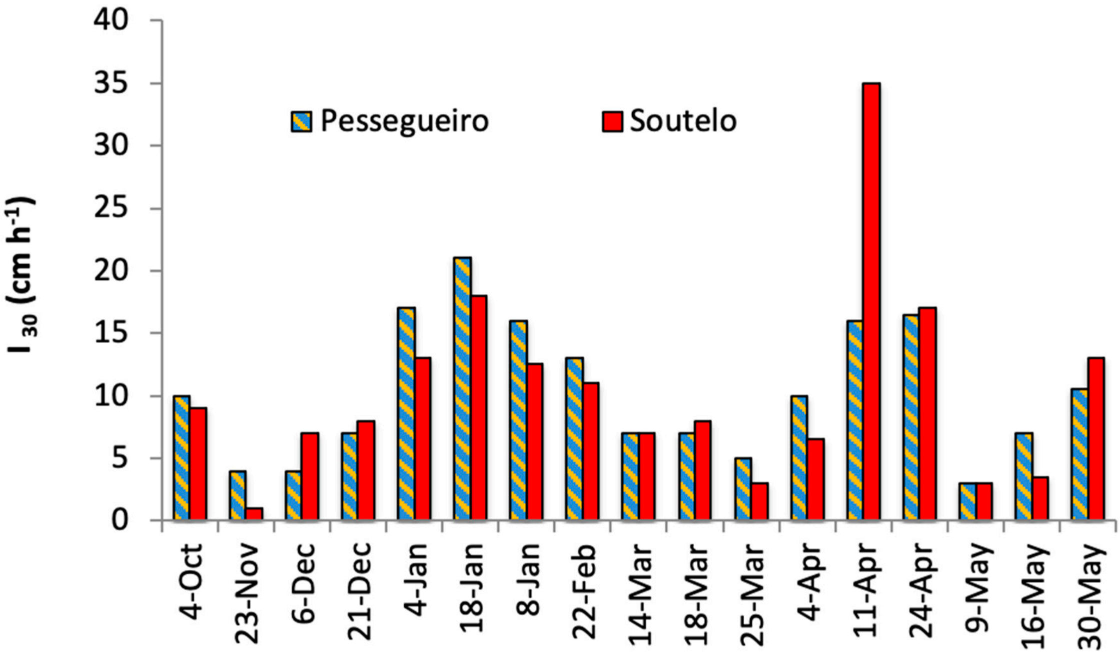


Figure 4. Maximum intensity of precipitation per 30 min I30 (cm h^{-1}) registered in the two study areas during the 17 rainfall events.

3.2. *Granulometric Composition and Stability of Aggregates*

The three study areas had the same textural class, sandy-loam in all cases (Table 2), however, Pessegueiro pre-fire had 7–8% more sand than the other areas with a lower quantity of silt and a similar quantity of clay but there were no significant differences between areas ($p > 0.05$).

Table 2. Textural class, sand (2–0.005 mm), silt (0.005–0.002 mm) and clay (<0.002 mm) (in %) and mean weight diameter (MWD, in mm) of the soil surface (0–2 cm) in the three study sites.

	Pessegueiro I	Pessegueiro II	Soutelo
Texture	loamy/sandy	loamy/sandy	loamy/sandy
Sand	67	59	60
Silt	20	25	28
Clay	13	16	12
MWD	2.8	2.1	2.3

The results of the aggregate distribution obtained by dry sieving showed that the soil had a weak aggregation when the MWD values were between 2.1 and 2.8 mm, where Pessegueiro I presented the highest value. However, these differences were not statistically significant ($p > 0.05$).

By analyzing the different fractions separately (Figure 5), it can be observed that there are no significant differences among the areas, but in Pessegueiro pre-fire the most abundant fractions are those between 2 and 10 mm in which almost 50% of their aggregates are included. However, in Pessegueiro post-fire the most abundant fractions are between 0.05 and 1 mm. Finally, in Soutelo, its aggregates are distributed mainly into fractions with sizes between 0.05–0.25 mm and 5–10 mm. Smaller-size aggregates are more easily erodible and increase splash erosion.

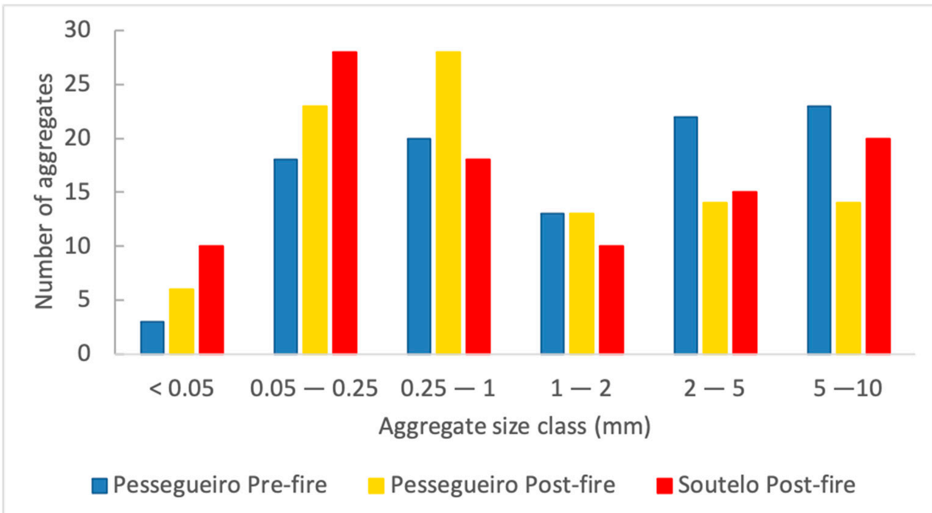


Figure 5. Distribution of aggregates per class size depending on the diameter length on the soil surface (0–2 cm) in the three study sites (blue) in Pessegueiro pre-fire (yellow) in Pessegueiro post-fire and (red) in Soutelo post-fire (n = 10).

3.3. *Influence of Time after Terracing in Splash Erosion*

When comparing the collection devices of splash erosion, it is observed that funnels are the ones that collect the most amount of splash soil per millimeter of precipitation (Figure 6), collecting much more soil than the cup system (Table 3). In fact, the comparison between cups and funnels, performed using the Wilcoxon test indicates that there are significant differences between the two systems in all cases ($p < 0.05$).

Figure 6. Figures showing the splash erosion in the upper part of the terrace (1st and 2nd floor) and in the bottom part of the terraces (4th and 5th terrace) for the three areas (**A**) Pessegueiro pre-fire (in green and blue), (**B**) Pessegueiro post-fire (in yellow) and (**C**) Soutelo post-fire (in red) recovered with cup devices (in dotted line) and with funnel devices (in continuous line) for measuring and splash erosion rates per millimeter of rainfall recovered in the three sample sites in (**D**–**F**) during the 17 rainfall events.

Table 3. Mean, maximum and standard deviation values of splash erosion rates found for the three sampled areas Soutelo post-fire, Pessegueiro II or post-fire and Pessegueiro I or pre-fire in g·m^{-2}·mm^{-1}.

	Cup			Funnel		
	Mean (g·m^{-2}·mm^{-1})	**Standard Deviation**	**Max (g·m^{-2}·mm^{-1})**	**Mean (g·m^{-2}· mm^{-1})**	**Standard Deviation**	**Max (g·m^{-2}· mm^{-1})**
Soutelo	1.12	0.63	2.30	2.64	1.56	5.60
Pessegueiro II	0.94	0.56	2.20	3.36	1.71	6.40
Pessegueiro I	0.06	0.05	0.22	0.44	0.29	1.20

As shown in Figure 6, the splash rate collected in the Soutelo and Pessegueiro post-fire is significantly higher ($p < 0.05$) than that collected in the area that had been terraced in Pessegueiro pre-fire, regardless of the device used for collection. In addition, the differences between the soil collected on the different terrace levels from the upper or the bottom part were not significant (Figure 6), and it was not possible to find any pattern in the maximum splash soil recovered.

Table 3 shows the rates of splash erosion values for the three areas studied. We observed a maximum of 2.3 g·m^{-2}·mm^{-1} of soil collected with cups in Soutelo, with a mean of 1.12 g·m^{-2}·mm^{-1}, whereas for funnels it increases for Pessegueiro II up to a maximum of 6.4 g·m^{-2}·mm^{-1} and a mean of 3.36 g·m^{-2}·mm^{-1}.

3.4. *Influence between Splash Erosion and Precipitation Variables*

Figures 7 and 8 show the relationship between splash erosion collected by both cups and funnels and accumulated precipitation during the seventeen rainfall events.

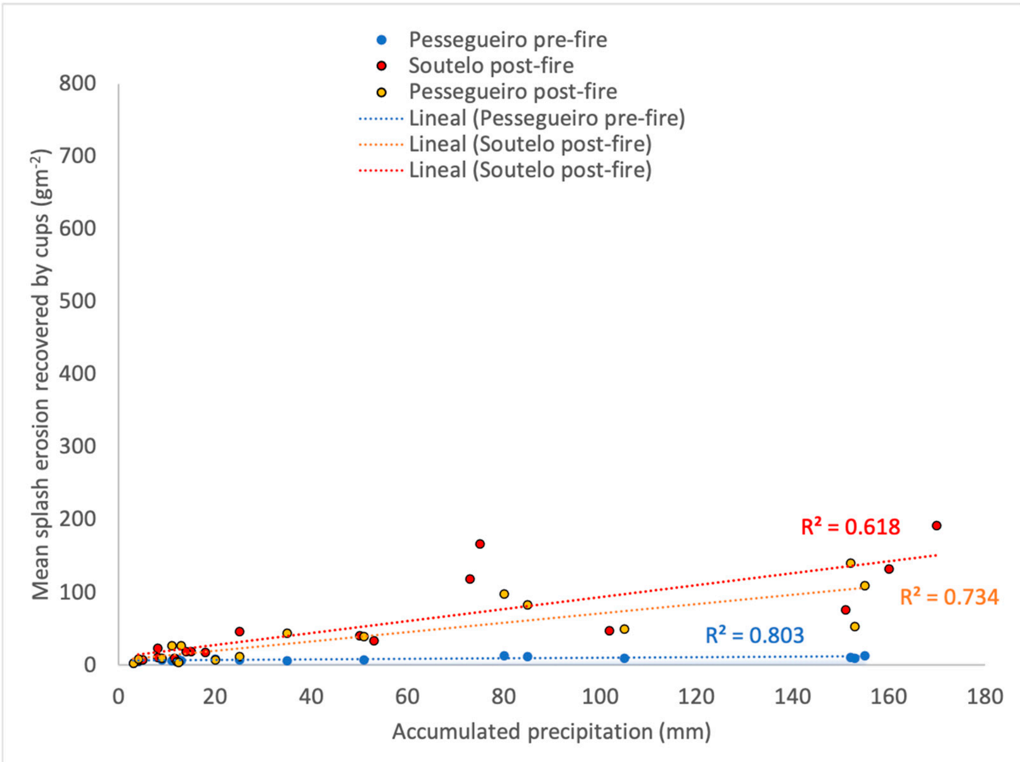


Figure 7. Relation between splash erosion rate with cups and accumulated rainfall in the three study sites over the 17 rainfall events.

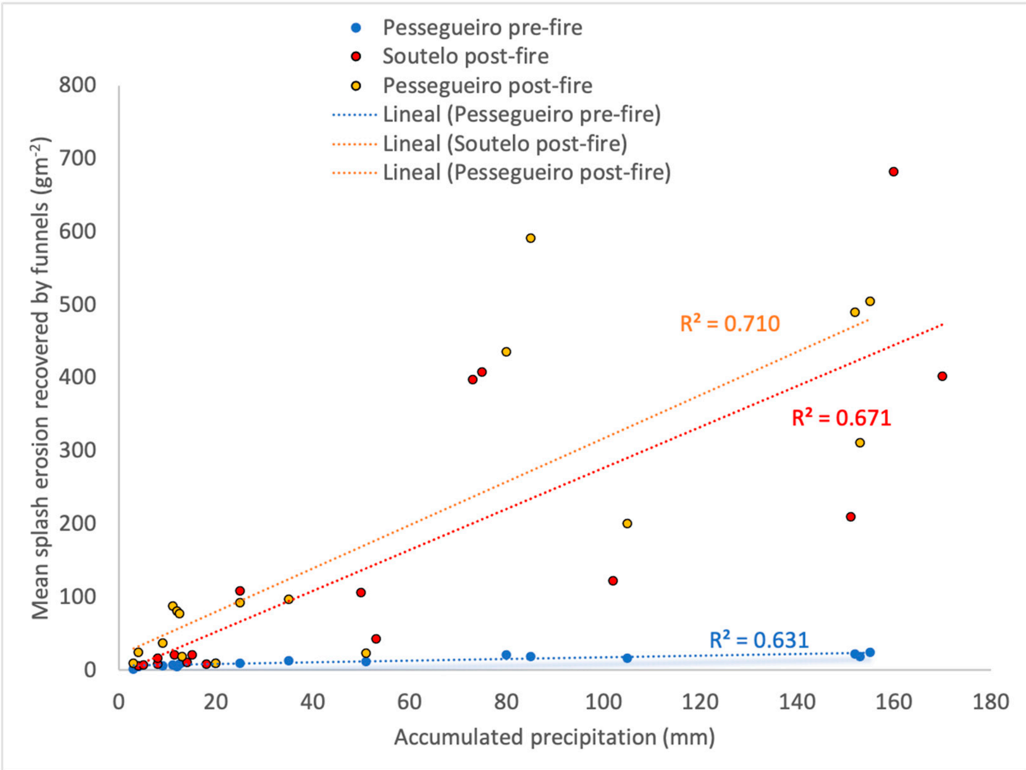


Figure 8. Relation between splash erosion rate with funnels and accumulated rainfall in the three study sites over the 17 rainfall events.

As can be observed in the area of Pessegueiro I, terraced more than a year prior, there is a very significant relationship ($p < 0.05$) between the precipitation and the splash erosion (R^2 = 0.8 for cups and R^2 = 0.63 for funnels) even though the accumulated rainfall was very low.

A significant relationship ($p < 0.05$) between precipitation and splash erosion also appears in recently terraced areas. The best correlation always appears in Pessegueiro II, regardless of the sampling device used. However, differences are detected based on the sampling device, showing in most cases best relationships with the erosion collected by the cup system, although it could be caused by the error in R estimates. When all the values taken in the three areas by each splash erosion device were related with the accumulated rainfall, a linear model was found, which could fairly accurately predict the mass of soil sprinkled by a certain amount of precipitation in both the cup (R^2 = 0.72) and funnel (R^2 = 0.67) systems.

4. Discussion

After analyzing the results obtained, it appears that the time at which the terracing was made has a clear influence on MWD, and is therefore crucial for estimating splash erosion, which is always significantly higher in areas recently terraced and with smaller aggregates [56]. In a number of papers, a reference was made to the fact that any tillage in the soil affects the organic matter content of the soil adversely and, consequently, the stability of its aggregates [66,67]. The disturbance of the soil strata produced during the construction of the terrace causes a decrease in fertility during the first years and a considerable loss of soil due to erosion processes [68,69]. In addition, the removal of the protection from the vegetation cover is another variable that induces this increase in erosion [43,70], although this is not so important in our case study because the vegetation in all the areas after fire is always quite sparse. The two most recently terraced areas showed a similar behavior, with no significant differences in observed erosion, whereas there were differences with the area terraced a longer time before the fire. In Table 3, it can be observed that the most recent terraces are those that always show a greater erosionability, whereas the terraces made one year before have stabilized, and this tendency is shown independently of the erosion device used. However, the erosion values of the two most recently terraced areas, Soutelo and Pessegueiro II, have peaks much higher than previously recorded in the area by Shakesby et al. [60]. Soutelo was terraced six months after Pessegueiro I, but it was terraced after a fire, and Soutelo showed much more splash erosion than Pessegueiro I. During the eight months of measuring at the three sites, which was done six months after terracing in Soutelo, we did not find a decrease over time in the production of splash erosion, so the time cannot explain all the differences found between terraced areas pre-fire and post-fire (Figure 6). As a result, the time from which the terracing was done is important, but not the only factor. The effect of being terraced before or after the fire seems to also have a big influence and other aspects such as the differences in rainfall characteristics or the conditions of the soil may have an effect.

A dry soil condition is much more sensitive to splash erosion and therefore, the timing of rainfall events can affect it [60]. From the analysis of different splash erosion recovered during different events, Shakesby found in their research also done in Portugal in a close area, that in drought conditions, a higher rate of erosion by splash was detected. This influence can be seen in our work, since the data of splash erosion indicate how the conditions of the special drought of the periods of 23 November and 21 December provided higher splash rates than during the other periods with more rainfall. However, in other periods such as 18 January, 11 April or 24 April, when precipitation was more abundant and frequent, less erosion by precipitation occurred per millimeter of precipitation. This is because the splashed soil recovered was divided into the rainfall received, to calculate the rate of precipitation, and although this allowed the comparison between different periods and areas, it assumed that the quantity of splash soil was much less with higher rainfalls. With this in mind, it is worth asking whether precipitation is similar in the two areas studied, or there is a space variation due to the distance between Soutelo and Pessegueiro. Because of the distance between both areas is only 5 km and the main wind direction coincides with the line connecting the two locations, the characteristics of the rainfall will be similar with more than 82% probability [71]. The numerous data registered by the rain gauges situated in both areas confirmed that there was no difference in the rainfall in both areas (Figures 3 and 4). In any case, we could avoid this problem by analyzing only the data from the two Pessegueiro areas that are together, with the same rainfall characteristics, exposition, soil and fire intensity with the only difference between them being that one was terraced before the fire and the other after it. By doing so, we had a great and unique opportunity of comparing the 40 sampling splash erosion points and their medium size of aggregates. This comparison suggested that Pessegueiro pre-fire always showed less splashed soil that Pessegueiro post-fire, no matter the height of the terrace level compared or the event of rainfall considered. Therefore, all our data confirmed that terracing prior to the fire produces less splash erosion than the soil recovered in the area terraced after the fire. Furthermore, the data from the Soutelo area, terraced post-fire, confirmed this tendency, because we recovered a similar quantity of splash soil than in Pessegueiro post-fire. This effect was detected for all the sampling points compared, independently of the splash device used. As a result, it is important to delay the terracing after the fire to decrease the splash erosion produced. It is not possible to compare this result with other articles because we could not find any other articles with splash erosion data from terraced and burned areas.

Another characteristic is that the size of aggregates was found to be smaller in areas terraced post-fire than in areas terraced pre-fire, and this may also influence the splash erosion. In the zone that had been terraced prior to the fire, after the fire the aggregates with a size larger than 2 mm were dominant, while in the zones terraced after the fire, the dominant size was smaller than 1 mm (Figure 5). According to Boix-Fayos et al. [72], the 1 mm aggregates are negatively related to the organic matter content and positively to the finer fractions of the soil, and this agrees with the texture results found in our study

(Table 2). This result is interesting when interpreting splash erosion, since, as the energy required to displace a smaller aggregate is smaller, in the soils terraced as a post-treatment, a greater mobilization of the aggregates will occur with the same rainfall. The greater existence of small aggregates in the post-fire terraced areas may be an effect of fire and subsequent terracing [73]. The effect of the fire itself on the organic matter content and the MWD of the aggregates [74] was added to the effect of the terracing [11]. Pessegueiro I or pre-fire had a higher percentage of sand that Pessegueiro II or post-fire. This little difference could be have been produced by a different intensity of the fire in Pessegueiro I, because temperatures higher than 400 °C could have caused a thermal fusion of clay particles [75], but it is not possible to be sure if this was the reason. In any case, there was an increase in sand fraction, which may somehow influence the size of aggregates [76].

The last objective was to conclude on the influence of the splash erosion device used, comparing the funnel and the cup. The funnel designed by Terry to avoid underestimating splash erosion [59] had a significant increase in the mass collected with respect to the cup device, as it was also detected in a previous analysis done in close areas [41]. In a previous work done in Soutelo, Fernández-Raga [41] found more soil collected with the funnel than with the cup, despite the fact that the funnel had a larger sampling area than the cup, and Torri and Poesen [77] observed a decrease of splash rates when increasing the sampling area. Our findings also show the largest mass of soil collected by the funnel, so the funnel prevents the loss of soil collected and possible washing of the samples. The funnel collects a triple amount of soil mass compared to the cup, but it is the latter that presents rates of soil splashed within the values collected by Shakesby et al. [60] and Terry [59] in a nearby area. Therefore, the last conclusion we can draw after these results, is that Pessegueiro I, a terraced pre-fire area, is the one with less splash erosion, no matter the devices used. Terracing can be a solution for areas with sites with a high fire recurrence, as a means of preventing erosion by splashing after future fires. However, it is not an advisable technique in recently burned areas, which are very sensitive to the use of heavy machinery and have very small aggregate sizes.

This work contributes to the sustainable development goals (SDG) 13 and 15, of climate action and life in terrestrial ecosystems, as it helps to increase knowledge in order to design optimal management treatments in areas with a high frequency of fire. It analyzed the impact that different management techniques may have on natural spaces, as well as assessed the benefit of choosing the most suitable time for the terracing of slopes, as an existing management alternative to minimize the loss of soil, which is the basic sustenance of any ecosystem after a forest fire.

5. Conclusions

From the analysis of the data collected during this sampling campaign in the three burned areas in Soutelo and Pessegueiro (Portugal) for eight months, the following points are concluded:

- The treatment of terraces was stabilized over time, increasing the mean weight diameter of the aggregates after eight months, which implies a greater stability.
- The highest rates of splash erosion always occurred in areas recently terraced.
- Burned areas terraced after fire had greater splash erosion than areas terraced before fire, independently of the method of measurement and rainfall intensity.
- There were no significant differences in splash erosion production between the upper and lower terraces.
- In any case, the analysis of the relationship between accumulated precipitation and splash erosion reflected the existence of a positive correlation, detected by both cups and funnels, with a dependence index higher than 0.6.
- Regarding the sampling devices, the funnel always collected three times more soil than the cup. This is due to the specific design of the funnel to avoid the washing and therefore, the loss of the splashed soil collected by the device.

Author Contributions: Conceptualization, M.F.-R. and R.F.; methodology, M.F.-R. and R.F.; software, M.F.-R.; validation, J.J.K.; E.M.-P. and M.F.-R.; formal analysis, M.F.-R. and M.A.S.M.; investigation, M.F.-R.; resources, J.J.K. data curation, J.J.K., E.M.-P.; writing—original draft preparation, M.F.-R.; writing—review and editing, M.F.-R.; visualization, E.M.-P.; supervision, R.F., E.M.-P. and J.J.K. All authors have read and agreed to the published version of the manuscript.

Funding: This study has been supported by the projects EROSFIRE (POCTI/AGR/60354/2004) and EROSFIRE-II (PTDC/AGR-CFL/70968/2006), funded by the Portuguese Foundation for Science and Technology (FCT) with co-funding by FEDER through the POCI2010 Program. The Junta de Castilla y León has also contributed to this Project with Grant LE014A07, and the Spanish Ministry of Education with Grant TEC2007-63216. This research was also funded partially by project PID2020-120439RA-I00 financed by MCIN/AEI/10.13039/501100011033.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors are grateful to Ana Braña for reviewing the translation and to Amaya Castro for her help with the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Marcos, E.; Tárrega, R.; Calvo, L.; Calabuig, E. *Efectos Del Fuego Sobre El Suelo Bajo Comunidades Arbustivas y Arbóreas de la Provincia de León. Los Brezales Como Caso de Estudio*; Cátedra de Divulgació de la Ciència; Universitat de València: Valencia, Spain, 2009; pp. 131–156.
2. Malvar, M.C.; Prats, S.A.; Nunes, J.P.; Keizer, J.J. Post-fire overland flow generation and inter-rill erosion under simulated rainfall in two eucalypt stands in north-central Portugal. *Environ. Res.* **2011**, *111*, 222–236. [CrossRef] [PubMed]
3. Montero de Burgos, J.L.; Bara, S.; Rigueiro, A. *Repoblación Forestal y Terrazas. Estudio Realizado en el Principado de Asturias y en la Provincia de Lugo*; Editorial Ceasa: Navia, España, 1989; Volume 3.
4. Varela, M.E.; Benito, E.; Keizer, J.J. Influence of wildfire severity on soil physical degradation in two pine forest stands of NW Spain. *Catena* **2015**, *133*, 342–348. [CrossRef]
5. Mataix-Solera, J.; Benito, E.; Andreu, V.; Cerdà, A.; Llovet, J.; Ubeda, X.; Martí, C.; Varela, M.E.; Gimeno-García, E.; Arcenegui, V.; et al. ¿Cómo estudiar la estabilidad de agregados en suelos afectados por incendios? Métodos e interpretación de resultados. In *Actualización en Métodos y Técnicas Para El Estudio de Los Suelos Afectados Por Incendios Forestales*; Càtedra de Divulgació de la Ciència; Universitat de Valencia: Valencia, Spain, 2010; pp. 109–143, ISBN 978-84-370-7887-8.
6. Varela, M.E.; Benito, E.; Keizer, J.J. Wildfire effects on soil erodibility of woodlands in NW Spain. *Land Degrad. Dev.* **2010**, *21*, 75–82. [CrossRef]
7. Ferreira, A.J.D.; Prats, S.A.; Ferreira, C.S.S.; Malvar, M.C.; Coelho, C.O.A.; Carreiras, M.; Esteves, T. Los incendios forestales en Portugal. Aportes para la comprensión del impacto en la degradación de suelos y aguas. *Cátedra Divulg. Cienc. Valencia* **2009**, *1*, 77–104.
8. Liu, W.; Luo, Q.; Lu, H.; Wu, J.; Duan, W. The effect of litter layer on controlling surface runoff and erosion in rubber plantations on tropical mountain slopes, SW China. *Catena* **2017**, *149*, 167–175. [CrossRef]
9. Mayor, A.G.; Bautista, S.; Llovet, J.; Bellot, J. Post-fire hydrological and erosional responses of a Mediterranean landscpe: Seven years of catchment-scale dynamics. *Catena* **2007**, *71*, 68–75. [CrossRef]
10. Pardini, G.; Gispert, M.; Emran, M.; Doni, S. Rainfall/runoff/erosion relationships and soil properties survey in abandoned shallow soils of NE Spain. *J. Soils Sediments* **2017**, *17*, 499–514. [CrossRef]
11. Welemariam, M.; Kebede, F.; Bedadi, B.; Birhane, E. Effect of community-based soil and water conservation practices on soil glomalin, aggregate size distribution, aggregate stability and aggregate-associated organic carbon in northern highlands of Ethiopia. *Agric. Food Secur.* **2018**, *7*, 42. [CrossRef]
12. Modrego, M.P.; Elena-Rosello, R. Efectos de las repoblaciones por terrazas con Pinus sylvestris L. en las propiedades físicas del suelo en el Sistema Ibérico soriano. *Investig. Agraria. Sist. Y Recur. For.* **2004**, *13*, 417–428.
13. Martínez-Casasnovas, J.A.; Ramos, M. Soil alteration due to erosion, ploughing and levelling of vineyards in north east Spain. *Soil Use Manag.* **2009**, *25*, 183–192. [CrossRef]
14. Xiong, M.; Sun, R.; Chen, L. Effects of soil conservation techniques on water erosion control: A global analysis. *Sci. Total Environ.* **2018**, *645*, 753–760. [CrossRef] [PubMed]
15. 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 Southeast Spain. *Hydrol. Process.* **2017**, in press. [CrossRef]
16. Tarolli, P.; Sofia, G.; Calligaro, S.; Prosdocimi, M.; Preti, F.; Dalla Fontana, G. Vineyards in terraced landscapes: New opportunities from Lidar data. *Land Degrad. Dev.* **2015**, *26*, 92–102. [CrossRef]

17. Tarolli, P.; Rizzo, D.; Brancucci, G. *World Terraced Landscapes: History, Environment, Quality of Life*; Springer: Cham, Switzerland, 2019; Volume 9, pp. 1–357. [CrossRef]
18. Chen, D.; Wei, W.; Chen, L. Effects of terracing practices on water erosion control in China: A meta-analysis. *Earth Sci. Rev.* **2017**, *173*, 109–121. [CrossRef]
19. Arnáez, J.; Lana-Renault, N.; Lasanta, T.; Ruiz-Flaño, P.; Castroviejo, J. Effects of farming terraces on hydrological and geomorphological processes. *A review. Catena* **2015**, *128*, 122–134. [CrossRef]
20. García-Comendador, J.; Fortesa, J.; Calsamiglia, A.; Calvo-Cases, A.; Estrany, J. Post-fire hydrological response and suspended sediment transport of a terraced Mediterranean catchment. *Earth Surf. Process. Landf.* **2017**, *42*, 2254–2265. [CrossRef]
21. Morgan, R.P.C. *Soil Erosion and Conservation*, 3rd ed.; Wiley-Blackwell: Malden, MA, USA; Oxford, UK; Carlton, Victoria, Australia, 2005.
22. Zhang, B.; He, C.; Burnham, M.; Zhang, L. Evaluating the coupling effects of climate aridity and vegetation restoration on soil erosion over the Loess Plateau in China. *Sci. Total Environ.* **2016**, *539*, 436–449. [CrossRef]
23. Li, X.H.; Yang, J.; Zhao, C.Y.; Wang, B. Runoff and sediment from orchard terraces in Southeastern China. *Land Degrad. Dev.* **2014**, *25*, 184–192. [CrossRef]
24. Liu, C.-W.; Huang, H.-C.; Chen, S.-K.; Kuo, Y.-M. Subsurface return flow and ground water recharge of terrace fields in northern Taiwan. *J. Am. Water Resour. Assoc.* **2004**, *40*, 603–614. [CrossRef]
25. Liu, C.-W.; Zhang, S.-W.; Lin, K.-H.; Lin, W.-T. Comparative analysis of temporal changes of multifunctionality benefit of two major rice paddy plains in Taiwan. *Paddy Water Environ.* **2010**, *8*, 199–205. [CrossRef]
26. Herrero-Borgoñon, J.J.; Rubio, J.L.; Hernandez, J.A. Pedological effects of reforestation in fores burned areas. In *Soil Erosion as a Consequencce of Forest Fires*; Geoforma Ediciones: Valencia, España, 1994.
27. 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. Landf.* **2009**, *34*, 1822–1830. [CrossRef]
28. Herrero-Borgoñon Pérez, J.J. *Impacto de Las Técnicas Forestales de Repoblaciones Sobre Procesos Erosivos Y la Fertilidad Del Suelo en Condiciones Mediterráneas*; Casa del Libro; Consejería de Agricultura, Alimentación y Pesca: Valencia, Spain, 1994; ISBN 978-84-482-0654-3.
29. Martins, M.; Machado, A.I.; Serpa, D.; Prats, S.; Faria, S.; Varela, M.E.; gonzalez-pelayo, O.; Keizer, J. Runoff and inter-rill erosion in a Maritime Pine and a Eucalypt plantation following wildfire and terracing in north-central Portugal. *J. Hydrol. Hydromech.* **2013**, *61*, 261–268. [CrossRef]
30. Hierro, R.S. Consideraciones sobre el impacto de la repoblación forestal en el suelo. *Ecología* **1990**, *1*, 453–462.
31. Pijl, A.; Barneveld, P.; Mauri, L.; Borsato, E.; Grigolato, S.; Tarolli, P. Impact of mechanisation on soil loss in terraced vineyard landscapes. *Cuad. Investig. Geográfica* **2019**, *45*, 287–308. [CrossRef]
32. Subhatu, A.; Speranza, C.I.; Zeleke, G.; Roth, V.; Lemann, T.; Herweg, K.; Hurni, H. Interrelationships between terrace development, topography, soil erosion, and soil dislocation by tillage in Minchet Catchment, Ethiopian Highlands. *Land Degrad. Dev.* **2018**, *29*, 3584–3594. [CrossRef]
33. Rodrigo-Comino, J.; Seeger, M.; Iserloh, T.; Senciales González, J.M.; Ruiz-Sinoga, J.D.; Ries, J.B. Rainfall-simulated quantification of initial soil erosion processes in sloping and poorly maintained terraced vineyards–Key issues for sustainable management systems. *Sci. Total Environ.* **2019**, *660*, 1047–1057. [CrossRef]
34. Novara, A.; Gristina, L.; Saladino, S.S.; Santoro, A.; Cerdà, A. Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyard. *Soil Tillage Res.* **2011**, *117*, 140–147. [CrossRef]
35. Keizer, J.J.; Martins, M.A.S.; Prats, S.A.; Faria, S.R.; Pelayo, O.G.; Machado, A.I.; Rivas, M.E.R.; Santos, L.F.; Serpa, D.; Varela, M.E.T. Within-in flume sediment deposition in a forested catchment following wildfire and post-fire bench terracing, north-central Portugal. *Cuad. Investig. Geográfica Geogr. Res. Lett.* **2015**, *41*, 149–164. [CrossRef]
36. Arnaez, J.; Lasanta, T.; Errea, M.P.; Ortigosa, L. Land abandonment, landscape evolution, and soil erosion in a Spanish Mediterranean mountain region: The case of Camero Viejo. *Land Degrad. Dev.* **2011**, *22*, 537–550. [CrossRef]
37. Shakesby, R.A. Post-wildfire soil erosion in the Mediterranean: Review and future research directions. *Earth Sci. Rev.* **2011**, *105*, 71–100. [CrossRef]
38. Malvar, M.C.; Martins, M.A.S.; Nunes, J.P.; Robichaud, P.R.; Keizer, J.J. Assessing the role of pre-fire ground preparation operations and soil water repellency in post-fire runoff and inter-rill erosion by repeated rainfall simulation experiments in Portuguese eucalypt plantations. *Catena* **2013**, *108*, 69–83. [CrossRef]
39. Chen, S.-K.; Liu, C.-W.; Chen, Y.-R. Assessing soil erosion in a terraced paddy field using experimental measurements and universal soil loss equation. *Catena* **2012**, *95*, 131–141. [CrossRef]
40. Ellison, W.D. Studies of raindrop erosion by single raindrops of varying kinetic energy. *Agric. Eng.* **1944**, *25*, 131–136.
41. Fernández-Raga, M.; Fraile, R.; Keizer, J.J.; Varela Teijeiro, M.E.; Castro, A.; Palencia, C.; Calvo, A.I.; Koenders, J.; Da Costa Marques, R.L. The kinetic energy of rain measured with an optical disdrometer: An application to splash erosion. *Atmos. Res.* **2010**, *96*, 225–240. [CrossRef]
42. Bochet, E.; Poesen, J.; Rubio, J.L. Mound development as an interaction of individual plants with soil, water erosion and sedimentation processes on slopes. *Earth Surf. Process. Landf.* **2000**, *25*, 847–867. [CrossRef]
43. van Dijk, A.I.J.M.; Bruijnzeel, L.A. Terrace erosion and sediment transport model: A new tool for soil conservation planning in bench-terraced steeplands. *Environ. Model. Softw.* **2003**, *18*, 839–850. [CrossRef]

44. Dijk, A.I.J.M.V.; Bruijnzeel, L.A.; Wiegman, S.E. Measurements of rain splash on bench terraces in a humid tropical steepland environment. *Hydrol. Process.* **2003**, *17*, 513–535. [CrossRef]
45. Hammad, A.H.A.; Børresen, T.; Haugen, L.E. Effects of rain characteristics and terracing on runoff and erosion under the Mediterranean. *Soil Tillage Res.* **2006**, *87*, 39–47. [CrossRef]
46. Patin, J.; Mouche, E.; Ribolzi, O.; Sengtahevanghoung, O.; Latsachak, K.O.; Soulileuth, B.; Chaplot, V.; Valentin, C. Effect of land use on interrill erosion in a montane catchment of Northern Laos: An analysis based on a pluri-annual runoff and soil loss database. *J. Hydrol.* **2018**, *563*, 480–494. [CrossRef]
47. Cuomo, S.; Chareyre, B.; D'Arista, P.; Della Sala, M.; Cascini, L. Micromechanical modelling of rainsplash erosion in unsaturated soils by Discrete Element Method. *Catena* **2016**, *147*, 146–152. [CrossRef]
48. Moss, A.J. Rain-impact soil crust. II. Some effects of surface-slope, drop-size and soil variation. *Aust. J. Soil Res.* **1991**, *29*, 291–309. [CrossRef]
49. Fernández-Raga, M.; García-Díez, I.; Campo, J.; Viejo, J.; Palencia, C. Effectiveness of a New Drainage System for Decreasing Erosion in Road Hillslopes. *Air Soil Water Res.* **2021**, *14*, 8722. [CrossRef]
50. Moss, A.; Green, P. Movement of solids in air and water by raindrop impact. effects of drop-size and water-depth variations. *Soil Res.* **1983**, *21*, 257–269. [CrossRef]
51. Campo, J.; Pérez, V.A.; García, M.E.G.; Pelayo, O.G.; Delgado, J.L.R. Cementing agents and aggregation in three different environments of a mediterranean forest soil upon heating. In *Proceedings of the Fuegored 2010 from 6th to 8 th october 2010: Jornadas Internacionales: Investigación y Gestión para la Protección del Suelo y Restauración de los Ecosistemas Forestales Afectados Por Incendios Forestales, Santiago de Compostela, España, 6–8 October 2010*; Consejo Superior de Investigaciones Científicas, CSIC, IIAG: Santiago de Compostela, España, 2010; pp. 123–126, ISBN 978-84-8408-583-6.
52. Fernández-Raga, M.; Campo, J.; Rodrigo-Comino, J.; Keesstra, S.D. Comparative Analysis of Splash Erosion Devices for Rainfall Simulation Experiments: A Laboratory Study. *Water* **2019**, *11*, 1228. [CrossRef]
53. Serrada, R. Apuntes de Repoblaciones Forestales. *Fucovasa. Madr.* **2000**, *1*, 77. Available online: https://pfcyl.es/sites/default/files/biblioteca/documentos/apuntes_de_repoblaciones_forestales.pdf (accessed on 17 November 2021).
54. Mutchler, C.K. Parameters for describing raindrop splash-knowledge of raindrop splash geometry is a prerequisite to splash erosion control. *J. Soil Water Conserv.* **1967**, *22*, 91–94.
55. van Dijk, A.I.J.M.; Bruijnzeel, L.A.; Rosewell, C.J. Rainfall intensity–kinetic energy relationships: A critical literature appraisal. *J. Hydrol.* **2002**, *261*, 1–23. [CrossRef]
56. Fernández-Raga, M.; Palencia, C.; Keesstra, S.; Jordán, A.; Fraile, R.; Angulo-Martínez, M.; Cerdà, A. Splash erosion: A review with unanswered questions. *Earth Sci. Rev.* **2017**, *171*, 463–477. [CrossRef]
57. Zambon, N.; Johannsen, L.L.; Strauss, P.; Dostal, T.; Zumr, D.; Cochrane, T.A.; Klik, A. Splash erosion affected by initial soil moisture and surface conditions under simulated rainfall. *Catena* **2021**, *196*, 104827. [CrossRef]
58. 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]
59. Terry, J.P. The development of a new device for measuring rainsplash erosion. *Swansea Geographer* **1989**, *26*, 54–63.
60. Shakesby, R.A.; Coelho, C.D.A.; Ferreira, A.D.; Terry, J.P.; Walsh, R.P.D. Wildfire Impacts on Soil-Erosion and Hydrology in Wet Mediterranean Forest, Portugal. *Int. J. Wildland Fire* **1993**, *3*, 95–110. [CrossRef]
61. Terry, J.P.; Shakesby, R.A. Soil hydrophobicity effects on rainsplash: Simulated rainfall and photographic evidence. *Earth Surf. Process. Landf.* **1993**, *18*, 519–525. [CrossRef]
62. Roldán Soriano, M. Estimation of Rainfall Kinetic Energy from Daily Precipitation. New Methodology for the Calculation of the "R" Factor. Application in Spain. In Proceedings of the 5o Congreso Forestal Español, Junta de Castilla y León, Ávila, Spain, 21–25 September 2009; Volume 1, pp. 1–17.
63. Roldán Soriano, M.; Fernandez Yuste, J.A. Sociedad Española de Ciencias Forestales. 2011; pp. 89–95. Available online: https://dialnet.unirioja.es/servlet/articulo?codigo=4244319 (accessed on 16 November 2021).
64. Kemper, W.D.; Rosenau, R.C. Aggregate Stability and Size Distribution. In *Methods of Soil Analysis*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 1986; pp. 425–442, ISBN 978-0-89118-864-3. Available online: https://eprints.nwisrl.ars.usda.gov/id/eprint/732/3/585.pdf (accessed on 16 November 2021).
65. Guitián Ojea, F.; Carballas, T. *Técnicas de Análisis de Suelos*; Santiago de Compostela: Pico Sacro, Spain, 1976; ISBN 978-84-85170-09-8.
66. Arias, N.; De Battista, J.J. Evaluación de métodos para la determinación de estabilidad estructural en Vertisoles de Entre Ríos. *Cienc. Suelo* **1984**, *2*, 87–92.
67. Bassi, S.; Kettunen, M.; Cavalieri, S. *Forest Fires: Causes and Contributing Factors to Forest Fire Events in Europe IP/A/ENVI/ST/2007-15 PE 401-003*; Policy Department Economic and Scientific Policy, Eurepean Parliament: Brussels, Belgium, 2008.
68. Dorren, L.; Rey, F. *A Review of the Effect of Terracing on Erosion*; Soil Conservation and Protection for Europe: Amsterdam, The Netherlands, 2003; Volume 1.
69. Nunes, J.P.; Bernard-Jannin, L.; Rodríguez Blanco, M.L.; Santos, J.M.; Coelho, C.D.O.A.; Keizer, J.J. Hydrological and Erosion Processes in Terraced Fields: Observations from a Humid Mediterranean Region in Northern Portugal. *Land Degrad. Dev.* **2018**, *29*, 596–606. [CrossRef]

70. Lasanta Martinez, T.; Arnaez, J.; Oserin, M.; Ortigosa, L.M. Marginal lands and erosion in terraced fields in the Mediterranean Montains. A case study in the Camero Viejo (Northwestern Iberian system, Spain). *Mt. Res. Dev.* **2001**, *21*, 69–76. [CrossRef]
71. Mishra, A.K. Effect of Rain Gauge Density over the Accuracy of Rainfall: A Case Study over Bangalore, India. *SpringerPlus* **2013**, *2*, 311. [CrossRef]
72. Boix-Fayos, C.; Calvo-Cases, A.; Imeson, A.C.; Soriano-Soto, M.D. Influence of soil properties on the aggregation of some Mediterranean soils and the use of aggregate size and stability as land degradation indicators. *Catena* **2001**, *44*, 47–67. [CrossRef]
73. Mataix-Solera, J.; Cerdà, A.; Arcenegui, V.; Jordán, A.; Zavala, L.M. Fire effects on soil aggregation: A review. *Earth-Sci. Rev.* **2011**, *109*, 44–60. [CrossRef]
74. Doerr, S.H.; Cerdà, A. Fire effects on soil system functioning: New insights and future challenges. *Int. J. Wildland Fire* **2005**, *14*, 339–342. [CrossRef]
75. Zihms, S.G.; Switzer, C.; Karstunen, M.; Tarantino, A. Understanding the effects of high temperature processes on the engineering properties of soils. In Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris, France, 2–6 September 2013; Volume 1, pp. 3427–3430.
76. Ulery, A.L.; Graham, R.C. Forest fire effects on soil color and texture. *Soil Sciece Soc. Am. J.* **1993**, *57*, 135–140. [CrossRef]
77. Torri, D.; Poesen, J. The effect of cup size on splash detachment and transport measurements. Part II: Theoretical approach. *Catena Suppl.* **1988**, *12*, 127–137.