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Soil erosion as a consequence of wildfires on recently abandoned citrus orchards in eastern Spain

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Abstract

Fire is a natural factor in the evolution of Earth ecosystems. Due to land abandonment wildfire are widespread in Mediterranean Type Ecosystems, which contribute to increase the soil erosion rates. Fire is also found in recently abandoned citrus orchards due to the quick vegetation recovery and the dry biomass found after 2 years of abandonment. Rainfall simulation experiments (1 hour at 45 mm h^{-1} in a plot of 0.25 m^2) show that although land abandonment on irrigated citrus orchards reduces the soil losses to very low values, the fire increase runoff and soil erosion. Water and soil losses are much lower in the fire-affected plots than on the cultivated ones due to the use of herbicides.

1 INTRODUCTION

Fire is a natural factor in the evolution of Earth ecosystems (Pausas & Keeley, 2009) and understood as a large herbivore (Bond & Keeley, 2005). Moreover, fire is being used by agricultural societies as a tool (Pynem 1995). The impact of fire in the Soil System has been studied in forests, scrublands and meadows (Cerdà & Robichaud, 2009), where it used to happen more often. Its impact has been reported mainly in natural, semi-natural or recently plant recovered, rainfed agricultural land (Cerdà & Mataix, SOlera, 2009; Mataix-Solera et al., 2007), but little is known of the effect in recently abandoned irrigated lands. Irrigation develops the most fertile soils in semiarid areas, and, once they are abandoned, the vegetation recovery is fast and the biomass is much larger than in non-irrigated land.

Orange plantations were established in Eastern Spain during the last two centuries and the citrus land is still growing thanks to technological improvements (drip irrigation systems, fertilizers, herbicides, pesticides and water pumping) (Piqueras, 1999) However, some of the traditional flood irrigated orchards are being abandoned, because of socio-economic factors, such as the age of the landowners (usually elderly people taking care of their

Table 1. Ponding time (s) for the cultivated, abandoned and burnt plots.

Plots	Cultivated	Abandoned	Burnt
1	234	1678	564
2	300	1987	657
3	320	2345	752
4	324	2347	865
5	356	2457	924
6	476	2474	546
7	545	2500	347
8	587	2765	387
9	654	3187	444
10	654	3402	536
Average	445.00	1452.0	602.20
Std. Dev.	157.13	510.18	195.37
Vc (%)	0.35	0.35	0.32

Table 2. Runoff coefficients (%) for the cultivated, abandoned and burnt plots.

Plots	Cultivated	Abandoned	Burnt
1	23.87	1.21	9.00
2	23.98	2.01	10.45
3	34.87	2.34	12.78
4	37.65	2.76	14.23
5	45.36	3.43	14.23
6	52.12	3.54	14.76
7	54.87	3.98	15.11
8	56.12	5.55	15.87
9	56.98	7.32	19.34
10	65.76	8.23	20.32
Average	45.16	4.04	14.61
Std. Dev.	14.50	2.31	3.48
Vc (%)	0.32	0.57	0.24

land), the size of the properties (0.3 ha in the study sites), the pressure of nearby, urbanized land and the low price of the citrus during the last two decades. Under these conditions, only the large properties (>8 ha) can afford to produce orange and clementines.

After the citrus orchards are abandoned, vegetation recovery is fast (less than 1 year) and in 5 years shrubs and lianas can even cover the trees, due to water availability and soil fertility, which has been improved through centuries of irrigation, manure and chemical fertilizers. However, as the abandoned orchards tend to be located near cities and towns, the risk of arson fires is very high (especially during Mediterranean hot and dry summers). And this is why they have become quite common during the last decade.

Little is known about the effect of fire on soil on recently abandoned citrus orchards, and on the effect on soils from other abandoned crops. Agricultural land abandonment is becoming a widespread process in the Mediterranean (García Ruiz, 2010), and one of the main factors that control the soil, sediment and water resources (García-Orenes et al., 2009).

2 OBJECTIVES

The main target of this study is to determine the impact of fire on soil erosion on recently abandoned citrus orchards. To delimit and understand the effect of land abandonment and the impact of fire on those orchards is the main objective to this paper. This is a pioneering approach to this topic, and a rainfall simulation strategy was use to shed some light and to plan further research works.

Table 3. Sediment concentration (g l^{-1})for the cultivated, abandoned and burnt plots.

Plots	Cultivated	Abandoned	Burnt
1	4.54	0.10	1.54
2	4.98	0.12	1.56
3	5.00	0.12	1.76
4	6.45	0.21	1.87
5	7.45	0.32	2.32
6	7.45	0.34	2.43
7	8.23	0.34	3.23
8	8.56	0.43	3.43
9	9.23	0.70	3.76
10	10.54	0.87	4.23
Average	7.24	0.36	2.61
Std. Dev.	1.99	0.26	0.98
Vc (%)	0.27	0.72	0.37

Table 4. Soil erosion (Mg ha^{-1} h^{-1}) for the cultivated, abandoned and burnt plots.

Plots	Cultivated	Abandoned	Burnt
1	0.60	0.00	0.08
2	0.66	0.00	0.09
3	0.96	0.00	0.12
4	1.34	0.00	0.15
5	1.86	0.01	0.18
6	2.14	0.01	0.20
7	2.48	0.01	0.27
8	2.64	0.01	0.30
9	2.89	0.03	0.40
10	3.81	0.04	0.47
Average	1.94	0.01	0.23
Std. Dev.	1.06	0.01	0.13
Vc (%)	0.54	1.21	0.59

3 METHODOLOGY

The research site was selected in the Canyoles River Valley, La Granja de la Costera municipality. A plot (0.68 ha) was burnt after 5 years of abandonment July 6th 2012. This plot was partially burnt due to the fire-fighters control of the fire, so that 0.34 ha were used as control (un-burnt) plot. The nearest cropped orchard (Cultivated) was used for comparison with the burnt and un-burnt abandoned orchard. At each of the three sites, 10 rainfall simulation experiments were conducted from July 26th to August 15th 2012. No natural rain was measured throughout the experimental period. The experiments consisted of a portable rainfall simulator (Cerdà & Doerr, 2007), entailed in a shower of distilled water that lasted for 1 hour at 45 mm h^{-1} (5- to 10-year return period at the study region) and wetted 1 m^2 with a plot of 0.25 m^2. Runoff was collected every minute and the samples were dried, so as to obtain the sediment concentration. From the runoff rates and the sediments, the soil erosion rates were calculated.

4 RESULTS AND CONCLUSIONS

The cultivated orchard was herbicide-treated, so the vegetation cover by weeds was null, and 80% of the orange plot was covered by the trees. The abandoned field was covered 100% by grass and orange trees. The burnt field showed some sprouts that covered less than 1 % of the plot one month after the fire, and a cover of orange branches and stems, up to 7 % of the plot surface. Fire-affected orchards had an ash layer (grey and black) that

ranged from 1 mm to 35 mm in thickness, with an average depth of 9.5 mm for the 800 points measured.

The soils in the study area are anthropogenic, as a result of levelling the terrains and the transport of soil material from nearby locations (traditionally collected from sites with high clay content). They have been irrigated and ploughed for centuries, whereby they lie over a flat topography (the flatter the soil surface, the lesser the water loss).

The 45 mm h^{-1} rainfall showed a contrasted hydrological response within the three surfaces, as shown by the variation coefficients. The Cultivated plots showed a faster ponding time (445 s), than the Burnt plots (602 s) and the abandoned ones (1452 s). The runoff rates were higher on the Cultivated plots than on the Abandoned and the Burnt sites (Table 2). The first ones contributed with a runoff coefficient of 45% of the total rainfall, whilst the Abandoned reached 4% and the Burnt ones 15%.

Sediment concentrations show the effect of plant cover and soil erodibility (rainfall properties and intensity were kept stable). Sediment concentration was much higher on the herbicide (Cultivated plots) treated orchards (7.24 g l^{-1} in average) than on the Abandoned plots (0.36 g l^{-1}). The Burnt plots reached an average sediment concentration of 2.61 g l^{-1}. Soil erosion registered during one hour at 45 mm h^{-1} rainfall intensity on 0.25 m^2 plots showed high erosion rates on the citrus orchard due to the lack of vegetation cover (1.94 Mg ha^{-1} h^{-1}), meanwhile, in the abandoned field the soil losses were negligible (0.01 (Mg ha^{-1} h^{-1}). After the fire, the soils losses reached an average value of 0.23 Mg ha^{-1} h^{-1} in the abandoned field.

The results shown here demonstrate that soil erosion on citrus orchards can be very high on bare soil (Cerdà et al., 2009) The land abandonment on irrigated citrus orchards reduces the soil losses to very low values, due to the protective herb cover. Similar findings were found on rainfed areas in the Mediterranean (Cerdà, 2008) and in nearby areas (Cerdà et al., 2012). The impact of fire in the immediately post-fire period showed that the ash cover was thin and runoff was increased in comparison to the abandoned field. Forest fires produced a deeper ash layer and reduced the runoff during the rains immediately after the fire [14]. In fire-affected, recently abandoned irrigated citrus orchards, fire triggered an increase in runoff and erosion, although both, water and soil losses are much lower in the fire affected plots than on the cultivated ones.

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