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Thermal shock and splash effects on burned gypseous soils from the Ebro Basin

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Abstract

Fire is a natural factor of landscape evolution in Mediterranean ecosystems. Middle Ebro Valley has extreme aridity, which determines a low plant cover and high soil erodibility of the soils, especially on gypseous substrates. The aim of this research is to analyze the effects of a moderate heating, on physical and chemical soil properties, mineralogical composition and susceptibility to splash erosion. Topsoil samples (15 cm soil depth) were taken in the Remolinos mountain slopes (Ebro Valley, NE-Spain) from two soil types: *Leptic Gypsisol* (LP) in a convex slope and *Haplic Gypsisol* (GY) in a concave slope. To assess the heating effects on the mineralogy we burned the soils at 105 °C and 205 °C in an oven and to assess the splash effects we used a rainfall simulator under laboratory conditions using undisturbed topsoil subsamples (0–5 cm soil depth of Ah horizon). LP soil has lower SOM and SAS and higher gypsum content than GY soil. Gypsum and dolomite are the main minerals ($> 80\,\%$) in the LP soil, while gypsum, dolomite, calcite and quartz have similar proportions in GY soil. Clay minerals (kaolinite and illite) are scarce in both soils. Heating at 105 °C has no effect on soil mineralogy. However heating to 205 °C transforms gypsum to bassanite, increases significantly EC in both soil units (LP and GY) and decreases pH only in GY soil. Despite differences in the content of organic matter and structural stability, both soils show no significant differences ($P < 0.01$) in the splash erosion rates. The size of pores is reduced by heating treatment or fire effect, as derived from variations in pF.

1 Introduction

Fire is a natural factor of landscape evolution in Mediterranean ecosystems. The important socio-economic changes that occurred in the last decades have contributed to an increase in forest fires (Shakesby, 2011; Mataix-Solera and Cerdà, 2009; Jordán and Cerdà, 2010), altering the fire regimes in terms of frequency, size, seasonality, recurrence as well as fire intensity and severity (Bento-Gonçalves et al., 2012; Keeley, 2009; Cerdà and Robichaud, 2009) causing severe effects on soils, water and vegetation (Bento-Gonçalves et al., 2012).

Fire affects soil properties directly by heat impact and ash incorporation and reduction or elimination of plant cover (Neary et al., 1999). Raindrop impact on burnt soil can lead to the structural degradation of the soil surface (Boiffin, 1985; Poesen and Nearing, 1993; Ramos et al., 2003). Aggregate breakdown liberates small soil particles forming a surface crust with low permeability to air and water (Llovet et al., 2008). Fire severity affects the susceptibility of soils to be degraded (Neary et al., 1999; Shakesby, 2011). The effects of heat on soil organic matter content (Mataix-Solera et al., 2002; González-Pérez et al., 2004), on structural stability (Mataix-Solera et al., 2011), on hydrophobic response (DeBano, 2000; Giovannini, 2012), and on infiltration capacity (Mallik et al., 1984; Imeson et al., 1992) have been also investigated. These characteristics represent factors in soil erodibility and soil degradation risk (Shakesby, 2011; Giovannini, 2012).

In the Central Ebro valley (NE-Spain) the climate, lithology and relief let the development of soils whose main constituents is gypsum, named gypseous soils (Herrero and Porta, 2000), occupying 7.2 % of the total area (Aznar et al., 2013). The global distribution of gypseous soils is associated to regions of arid and semi-arid climate (FAO, 1990; Verheye and Boyadgiev, 1997), and is necessary analysis of edaphic modifications that affect agricultural areas important of the central sector of the Ebro valley.

To Neary et al. (1999) some of the changes that occur in the soil in function of the temperature are: protein degradation and biological tissue death at 40–70 °C; dehydration of certain roots or death at 48–54 °C; death of certain seed at 70–90 °C; death of edaphic microorganisms at 50–121 °C; and destructive distillation and combustion of about 85 % of the organic horizon at 180–300 °C. In relation to reached temperatures in a semiarid area, Pérez-Cabello et al., (2012) obtained maximum values between 400–800 °C during a prescribed fire, and heat transfer values on the soil surface until 110 °C – in controlled burning-plots on semiarid shrubland –, because there are a low vegetation cover, with small shrub patches on gypseous soils. Although the temperatures reached in burned semiarid woodlands may not be very high, they may be enough to cause some edaphic changes. Some works on gypseous soils are focused on its genesis and classification (Herrero and Porta, 2000; Artieda et al., 2006; Badía et al., 2013a), plant recovery (Badía and Martí, 2000), erosion processes (Gutiérrez and Gutiérrez, 1998; Desir, 2001) or mineralogy (Laya et al., 1998; Herrero and Porta, 2000; Herrero et al., 2009), but there are few studies on their post-fire hydrological response (León et al., 2011) and erosivity (León et al., 2012).

To assess changes on soil properties and erosion by splash, rainfall simulations are a remarkably useful tool, especially in semiarid areas, where precipitation regime is irregular, having intense and short-living events (Cerdà, 1995; Seeger, 2007; León et al., 2012).

The aim of this research is to analyze the heating effects after a moderate fire, on physical, chemical soil properties, mineralogical composition and susceptibility to splash erosion by mean of rainfall simulation.

2 Materials and methods

2.1 Study area

The gypseous soils were sampled in the Zuera Mountains in the central sector of the Ebro basin (NE-Spain), near the town of Remolinos. This area has been regularly affected by wildfires that promoted the development of shrub communities (*Retama sphaerocarpa* L., *Rosmarinus officinalis* L., *Lygeum spartum*, *Gypsophila struthium* subsp. *hispanica* and *Ononis tridentatae*) and small patches of forest (*Pinus halepensis* Mill. with an understory of *Quercus coccifera* L.), covering the north slopes (Ruiz, 1990; Gracia, 2005).

The study area sits on staggered relief (200–748 m), where gypseous soils predominate in the low slopes (Badía et al., 2013a). The climate is continental-mediterranean, with annual precipitation until 450 mm, with maxima autumn and spring and extreme temperatures that can vary between –7.1 °C and 36.5 °C. The mean annual evapotranspiration reaches 1406 mm (using FAO56 by Penman Monteith method) and it is enhanced by strong winds, which makes the water deficit to be one of the highest in Europe (Herrero et al., 2009).

2.2 Soil sampling and preparation

Topsoil blocks (20 cm × 20 cm × 15 cm) were sampled in two different geomorphic position in the head of the slope with unburned gypseous soils, classified as *Leptic Gypsisol* (skeletic) by IUSS (2007), with a sequum Ahy-R (which we will call henceforth LP), and in the foot of the slope, with burned gypseous soils, *Haplic Gypsisol* (humic) with a sequum Ah-By-Cy (which we will call henceforth GY). The soils are described in more detail in Badía et al. (2013a). The samples had a different texture: sandy loam to GY, and loamy to LP soil. The GY topsoil has a different distribution of the main mineralogical components, being the gypsum, dolomite, calcite and quartz around 18–25 % each component. Gypsum and dolomite are the main minerals (> 80 %) in the LP topsoil. Clay minerals (kaolinite and illite) are scarce in both soils.

15 replicates of each soil block were taken in unaltered metallic cylinders (5 cm × 6 cm) and covered the bottom with a metallic plate (Fig. 1). The samples were dried for one month at 25 °C, controlled, and heated at 35 °C (all samples), 105 °C (ten samples of each soil) and 205 °C (five samples of both soils) for 30′ to observe the soil changes after the heating.

2.3 Rainfall simulation

To assess changes on splash erosion the rainfall simulator is especially useful, in semiarid areas, where precipitation regime is irregular, having intense and short-living events (Cerdà, 1995; Seeger, 2007; León et al., 2012). We used a portable rainfall simulator with a Lechler nozzle (Ref. 460.608.30) at 2 m height (Iserloh et al., 2011), in the Kraaijenhofvan de Leur Laboratory for water and sediment dynamics at Wageningen

University (Fig. 2, left). Small rainfall collectors were used for the detailed determination of the rainfall intensity on the simulation area (1.16 m^2). Drop size (d_{50} 1–1.5 mm) and the kinetic energy (5.81 $J\,m^{-2}\,mm^{-1}$) were measured with Thies laser disdrometer (Fister et al., 2011). The simulation time was 20 min with an intensity of rain of 53 $mm\,h^{-1}$ and demineralized water (with pH 7.1 and an EC of 36.7 $\mu S\,cm^{-1}$) was used. Simulation plot was divided into four subplots that previously were calibrated with the laser disdrometer (Fig. 2, right).

2.4 Soil analysis

Different parameters were measured on the gypseous soils: pH, soil salinity (EC), soil organic matter (SOM), gypsum content (GC), soil aggregates stability (SAS), matric potential (pF or Ψ_p^m), soil texture and mineralogy of fine fraction.

The soil sample was sieved to 2 mm. The pH was measured in a 1 : 5 dilution with distilled water with a pH-meter, while the EC was measured in a 1 : 10 dilution (25 °C), with a conductivimeter after filtering the diluted sample. For measuring SOM by weight difference, it was taken about 30 g of material crushed and sieved to 2 mm and it was first dried at 105 °C (24 h) and heated to 550 °C (3 h). SOM was calculated by gravimetry. Gypsum content was calculated by thermo-gravimetry (Vieillefon, 1979; Herrero and Porta, 2000; Lebron et al., 2009). SAS was calculated using an Eijkelkamp wet sieving device (Schinner et al., 1996). To measure the matric potential (pF) we used Sand-Box method of Eijkelkamp was used to pF 0, 1, 1.5 and 2. The volumetric pressure plate extractor (Richards, 1947) was used for measured the pF 3 and 4.2, by breaking up and sieving the sample to 2 mm. The soil texture was measured with a Malvern Mastersizer 2000, correcting the clay value according to Taubner et al. (2009) equation ($y = 3089x - 2899$). Mineralogical composition of the fine fraction (< 2 mm) of each soil type and after each heat treatment was determined separately. The analysis was performed in the laboratory of Geology at Trier University, using a Siemens D500 diffractometer. The diffractograms were evaluated by Diffrac Plus Release 2000 EVA 6.0.0.1. The splash effect was measured by differences of weight, before and after the rainfall simulation and two weeks after the experiment, after air drying at 35 °C. To avoid loss of material by percolation, samples were closed at the bottom by a metal plate.

2.5 Data analysis

A two-factor analysis of variance (ANOVA) was used to test for differences between the soil type and temperature – independent variable –, for splash, pH, EC, SOM, SAS and gypsum content – dependent variable –, for each set of treatments. The separation of means was made according to Tukey's honestly significant difference test at an alpha level of 0.05 for all the parameters analyzed. Prior to ANOVA, the variables were tested for normality using the Kolmogorov–Smirnov test, and SOM, SAS and gypsum content were arcsine of the square root-transformed and the others were ln-transformed to improve the normality of the data. The analyses were performed using the RStudio version 3 statistical software.

3 Results and discussion

3.1 Thermal shock

The values of SOM, SAS and GC are significantly different for both soil types. The LP soil sample, placed on head slope, has lower SOM, SAS and higher GC than GY soil sample, a more developed soil on foot slope with higher plant cover (see Table 1).

Heating decreases significantly pH and increases EC and soil loss by splash effect ($p < 0.05$). The decrease in pH is highest at treatment 205 °C, being GY more susceptible to a decrease of pH than LP (7.8–7.9, respectively; see Table 1). The EC increased significantly with temperature, especially at 205 °C, doubling its value (from 2.1 dS m^{-1} for 35 °C to 4.2 dS m^{-1} for 205 °C, see Fig. 3). The SOM decreased significantly in the LP at a temperature of 205 °C but not in GY topsoil which can be related to SOM quality. The GY topsoil, more organic than the LP topsoil, is not significantly affected by the heat (Table 1). SAS was lower on LP than on GY, independently of the treatment (33.8–55.5 %, respectively), and the gypsum content in GY (15.5 ± 1.5 %) soil is lower than in the LP soil (39.9 ± 2.1 %). After heating, it suffers only a considerable decrease in GY. Another remarkable difference between soils is that the water retention capacity available to plants is greater in the GY than LP topsoil (Fig. 5).

The statistical significance of all the relationships between the dependent variables (splash, pH, EC, SOM, SAS and gypsum content) are given in Table 1. The differences are showed in each row being not significantly different the parameters with the same lowercase letter (i.e. the splash for both soil types). The statistical significance is shown by soil types (LP and GY) and temperature effect (35 °C, 105 °C, 205 °C), and it was significantly ($p < 0.05$), using the ANOVA. It must be noted that the temperature effect shows statistical significance for the pH, EC and splash ($p < 0.05$).

In this study there was observed only a little, but significant decrease in soils pH at 205 °C in both soils. This reduction could be a result of the oxidation, the exposure of new surfaces, the dehydration of colloids and the consequent decrease of the soil buffer action (Giovannini et al., 1990). Similar pH decrease was obtained by Badía and Martí (2003), after heating a gypseous soil at 250 °C.

Mineralogical components of these gypseous soils can be modified by heating above 50 °C (Vieillefon, 1979; Herrero and Porta, 2000; Lebron et al., 2009) to transform the gypsum ($CaSO_4 \cdot 2H_2O$) into bassanite ($CaSO_4 \cdot 1/2H_2O$). The intensity of the changes in the soil depends on the temperature reached at different depths, on the time of resilience of the temperature peaks and on the stability of the various components of the soil (Gónzalez-Pérez et al., 2004; Terefe et al., 2008; Granged et al., 2011). Therefore the study was concentrated on the upper 6 cm of the soil samples. The range of heating 105 °C to 205 °C was employed because during a fire, only a small part of the heat is transmitted to the first few centimeters of soil (Badía et al., 2013b). Pérez-Cabello et al. (2012) have recorded, maximum temperatures ranging from 400–800 °C on the soil surface and 29–110 °C in the upper soil centimeters (6.5; 2.5; 1 cm of soil depth). Other authors recorded 50 °C at 2.5 cm of depth on shrub and 90 °C at the same depth on a less dense shrub (Luchessi et al., 1994). Mataix-Solera (1999) recorded 22 °C at 5 cm soil depth in shrublands with Meditteranean gorse (*Ulex parviflorus)* cover.

The increase of EC at 205 °C may be related to solubilization and incorporation of cations from the ashes (DeBano et al., 1977; Badía and Martí, 2003) or to the increased amount of soluble inorganic ions resulting from the combustion of soil organic matter (Sanroque et al., 1987).

The trend reduction in the soil organic matter and the soil aggregate stability by heating in LP soil was explained by some authors (Cerdà, 1998; Giovannini, 2012) as organic matter decline and the consequent destruction of aggregates and increased soil erodibility (Sanroque et al., 1987).

Increases in organic matter after low intensity fires (Mataix-Solera et al., 2011), may explain the increase in soil aggregate stability, even with the passage of time (Díaz-Fierros et al., 1987; Bento-Gonçalves et al., 2012). The reduction of soil aggregate stability after heating may be related to a decrease of soil organic matter (DeBano et al., 1998; Cerdà, 1998; Badía and Martí, 2003), and changes in the mineral composition of the soil (Varela et al., 2002). Giovannini (2012) observed that soil aggregate stability increased at about 150 °C and again about 500 °C, by the combustion of the soil organic matter, as transformations of iron oxides cemented soil aggregates. Badía and Martí (2003) have observed as organic matter in gypseous soils drops significantly from 2.8 % to 2.2 % when heated to 250 °C. This decrease is accompanied by a significant reduction of the structural stability from 70 to 50 %. Novara et al. (2011) observed a redistribution of the OM by water erosion and degradation at the upper part of the hillslopes. Despite the variety of results and explanations issued by different authors, similar values of EC, pH, OM and SAS have been found in other works in gypseous soils (Badía and Martí, 2000, 2003; Cantón et al., 2001; Badía et al., 2008, 2013a; Ries and Hirt, 2008; Lebron et al., 2009).

The water potential increases after heating at 105 °C can relate to experimental fires of low intensity; the water retention values descend both surface and in depth, and the bulk density increases in the outermost layer due to the reduction of micropores

(Ralston and Hatchell, 1971; Boyer et al., 1994). Wahlenberg et al. (1939), observed in annual fires that bulk density increased and soil porosity was reduced due to aggregate dispersion by impact of rain, which can clog pores (Bower, 1966; Moehring et al., 1966). Giovannini (2012) found in sandy soil a decrease in porosity when the temperature increased, being most notably at 170–220 °C and increases in bulk density and decreases of soil porosity related to the decrease of soil organic matter by soil heating. However, Mallik and FitzPatrick (1996) concluded that soil porosity increased directly after fire.

3.2 Mineralogical changes

The main mineralogical component that is affected by heat is the gypsum ($CaSO_4 \cdot 2H_2O$). The gypsum content in topsoil sample was higher in *Leptic Gypsisol* (LP), than in *Haplic Gypsisol* (GY) (Fig. 4 and Table 1). The gypsum content was higher in Ahy horizon of LP than in the GY, as the gypsum content did not vary with heating at 105 °C in both soils, but it was significantly reduced at 205 °C in GY. The thermal increase transforms the gypsum into bassanite ($CaSO_4 \cdot 1/2H_2O$). Contrasting, the LP soil with a 50 % of gypsum in its fine earth fraction, it is also partly transformed into bassanite when it was heated at 205 °C.

Bassanite could not be found in the samples heated at 105 °C, but it was in those heated at 205 °C. When the gypsum is heated up to 105 °C, only a small fraction (13–19 %) of gypsum is removed; moreover, subsequent partial rehydration in the laboratory results in the formation of bassanite at relative moisture below saturation (Lebron et al., 2009). Some data reported in the literature show that, at 105 °C, the gypsum crystal loses 13–19 % of its mass (Artieda et al., 2006), corresponding to the two water molecules. Consequently Lebron et al. (2009) concluded that the temperature at which total water disappears is around 163 °C, since fast heating does not allow enough time for diffusing the water through the crystal. For this reason in the mineralogical analysis bassanite did not show up until reaching 205 °C.

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◀◀ ▶▶
◀ ▶
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

3.3 Splash effects

The soil loss due to splash effect was higher in GY ($0.8 \pm 0.2\,kg\,m^{-2}$) than in LP soils ($0.5 \pm 0.3\,kg\,m^{-2}$). The first one suffered a significant soil loss after heating ($1.4 \pm 0.2\,kg\,m^{-2}$), whilst the latter one was no sensitive to heating (Table 2).

The pF curve was similar for both soils, decreasing as the soil dries. The pF was higher in GY (46.7 ± 2.5) than in LP (39.9 ± 1.0) to values of 3 and 4.2 pF, and from here the trend is reversed, so that the LP soil ($9.2 \pm 2.4\,\%$) had higher pF than GY (6.8 ± 0.3) (Fig. 5).

The splash rates increased when soil aggregate stability (SAS) increased in LP (0.5–0.7 $kg\,m^{-2}$). In GY the splash rates decreased when SAS increased (0.6–1.4 $kg\,m^{-2}$) (Fig. 6).

There is not trend in the relationship between splash rate and soil organic matter. The splash rates increase when soil organic matter (SOM) decreases in LP ($0.5 \pm 0.5\,kg\,m^{-2}$). In GY the splash rates decrease when the SOM increases ($0.6 \pm 0.2\,kg\,m^{-2}$) (Fig. 7).

Splash erosion increases significantly by heating in GY but not in LP topsoil. The SAS and the splash rate are correlated positively in LP. While SAS is correlated negatively with the splash rate in GY (see Fig. 6), the soil aggregate stability is significantly by soil type. In dry soil samples, crusting and cracking are detected, particularly in the *Haplic Leptosol* (LP). Herrero et al. (2009) explained that upon drying, the salt migration is an important weathering process related to the formation and widening of crack and fissures, which can transmit additional water for further salt solution and crystallization. Splash production was higher in *Haplic Leptosol* (LP) than in*Haplic Gypsisol* (GY), in the samples heated at 105 °C; maybe it is explained because the SAS and SOM were lower in LP. The impact of raindrops on bare soil aggregates destroys the aggregates affected by fire (Ellison, 1944; Moore and Singer, 1990). Lower infiltration rates and higher surface runoff are explained by clogging pores and favoring entrainment of particles and nutrients, which may result in the formation of physical crusts (Mc

Intyre, 1958; Mataix-Solera et al., 2011). Nevertheless, Bresson and Boiffin (1990) and Ries and Hirt (2008) did not find any clear separation in inter-aggregates because of the short transport path or the transport via splash.

Difference between pF 3.2 and pF 4.1, indicating the amount of water capillary absorbable has been reduced after wetting by rain and subsequent heating (see Table 2), but more experiments should be conducted to confirm these changes. The burned samples (GY) show a lower porosity (see Fig. 5), and the splash production is higher than unburned samples (LP). However, the opposite occurs with the heated samples, because the porosity in GY is higher than in the LP. The rainfall simulation increases the water content to pF's higher (in both soils), because there is water retention with a major energy by increase the microporosity (lost of macroporosity). Gypseous soil had a significantly low infiltration value, because the growth of gypsum crystals in pre-existing pores decreases water flow (Poch and Verplancke, 1997). The SOM and the splash rate are correlated positively in LP. While the soil aggregate stability with the splash rate is correlated negatively in GY to 105 °C, changing to positively at 205 °C (see Fig. 7). Moreover, gypseous soils have low organic matter content and aggregate stability that elicit a slow micropore flow (Martí et al., 2001). Lasanta et al. (2000) and Desir et al. (1995) observed the same results in similar soils where microcrust was developed. The precipitation as microcrystalline gypsum could relate to root channels, where the moisture conditions were different from those within the groundmass (Aznar et al., 2013). The progressive loss of weigh could be due by dissolution of some soluble mineral within the sample in the wetting phase or by the enhanced dehydration of some mineral as a consequence of oven heating. When water dissolves gypsum, some new pore space increases the water intake in the following saturation phase and this progressive enlargement of pre-existing pore volume may enhance further weathering through solution (Cantón et al., 2001).

4 Conclusions

Heating decreases significantly pH and increases EC and soil loss by splash effect. On the other hand, SOM and SAS are not modified by moderate heating. The SOM, positively correlated with the SAS, is higher in the GY than in the LP topsoil according to their slope position and plant cover. Nonetheless soil loss by splash is three times higher in GY than in LP topsoil. Soil loss by splash increased significantly ($P < 0.05$) to 205 °C only in GY topsoil. Heating at 205 °C caused a partial dehydration of gypsum to bassanite, in both gypseous soils (LP and GY).

Rain events increase the water content at high pF's (in both soils), therefore more water is retained with high energy due to an increase of microporosity (ie a loss of macroporosity).

At 205 °C, the mineralogical changes appear and at this moment is when the splash increases.

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Table 1. Mean value, standard deviation, mean comparison and their probability (ANOVA) according to the soils (S), temperature (T) and both ($S \times T$), of the studied variables. [a] $p < 0.05$; [b] $p < 0.1$. For each soil property (line), different letters show significant differences ($P < 0.05$) among means, by Post Hoc Tukey test.

Soil unit									
Cover	Leptic Gypsisol (LP)			Haplic Gypsisol (GY)			Probabilty		
Temp (°C)	25	105	205	25	105	205	Soil (S)	Temperature (T)	$S \times T$
pH	7.9 ± 0.07 bc	7.9 ± 0.00 c	7.8 ± 0.04 b	7.8 ± 0.00 b	7.8 ± 0.06 bc	7.4 ± 0.01 a	0.041^{a}	0.039^{a}	$< 0.001^{b}$
EC ($\mathrm{mS\,cm^{-1}}$)	2.1 ± 0.01 a	2.1 ± 0.00 a	4.2 ± 0.18 b	2.1 ± 0.01 a	2.1 ± 0.01 a	4.1 ± 0.02 b	0.974	$< 0.001^{b}$	$< 0.001^{b}$
SOM (%)	3.4 ± 0.11 ac	3.3 ± 0.03 ab	2.3 ± 0.01 a	3.9 ± 0.09 bc	4.8 ± 0.14 c	4.5 ± 0.11 bc	$< 0.001^{b}$	0.506	0.003^{b}
SAS (%)	33.8 ± 2.34 a	38.9 ± 10.12 ab	35.7 ± 1.61 ab	55.5 ± 11.56 ab	60.7 ± 1.44 b	52.4 ± 1.69 ab	$< 0.001^{b}$	0.868	0.025^{a}
Gypsum (%)	39.9 ± 2.13 c	46.2 ± 0.87 c	45.0 ± 4.60 c	15.5 ± 1.52 ab	22.3 ± 3.94 b	11.1 ± 0.34 a	$< 0.001^{b}$	0.983	$< 0.001^{b}$
Splash ($\mathrm{kg\,m^{-2}}$)	0.5 ± 0.3 a	0.7 ± 0.2 a	0.5 ± 0.5 a	0.8 ± 0.2 a	0.6 ± 0.2 a	1.4 ± 0.2 a	0.384	0.014^{a}	0.240

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◀| |▶
◀ ▶
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

Table 2. Mean value and standard deviation about the values of the pF (the base 10 logarithm of the water potential in cm). (LP) *Haplic Leptosol* and (GY) *Haplic Gypsisol*, before and after the rainfall simulation. [a] Difference between pF 4.2 and pF 3.

Treatments		pF						
Rainfall	Temp (°C)	0	1	1.5	2	3	4.2	Dif.[a]
		0 kPa	1 kPa	5 kPa	10 kPa	100 kPa	1500 kPa	Dif.[a]
LP before	Field sample	39.9 ± 1.05	34.3 ± 2.12	28.7 ± 1.37	21.8 ± 0.78	12.6 ± 2.65	9.2 ± 2.48	3.4
LP after	35	37.9	32.8	29.3	23.4	27.6 ± 2.93	19.6 ± 0.30	8.0
	105	43.9	40.7	35.2	27.4	18.8 ± 0.06	15.0 ± 0.02	3.7
	205	42.0	40.5	35.2	27.8	21.2 ± 0.10	17.4 ± 0.13	3.9
GY before	Field sample	46.7 ± 2.51	41.4 ± 1.69	35.8 ± 0.80	27.2 ± 0.31	10.6 ± 0.74	6.8 ± 0.38	3.8
GY after	35	41.2	41.0	36.4	28.6	27.6 ± 0.56	15.0 ± 0.24	12.6
	105	50.4	44.7	38.7	30.0	15.9 ± 0.56	11.9 ± 0.13	3.9
	205	44.6	40.0	35.1	28.3	13.7 ± 0.71	10.0 ± 0.24	3.7

Fig. 1. Samples preparation: **(A)** block extraction, **(B)** subsamples of the blocks; and **(C)** subsamples preparation.

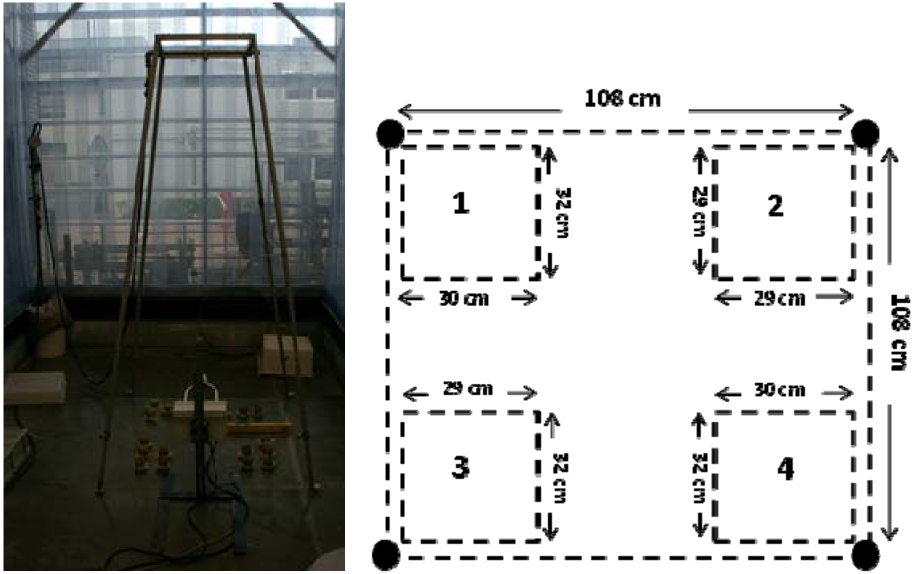

Fig. 2. Rainfall simulator (left) and subplots – 1,2,3,4 – diagram (right).

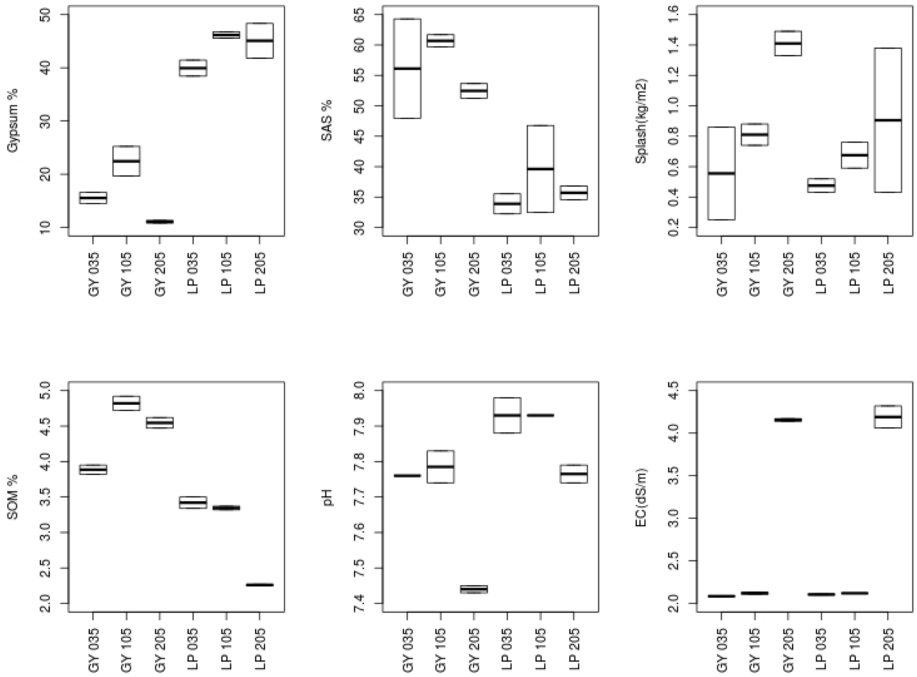

Fig. 3. BoxPlot of soil properties. (LP) *Leptic Gypsisol* and (GY) *Haplic Gypsisol*.

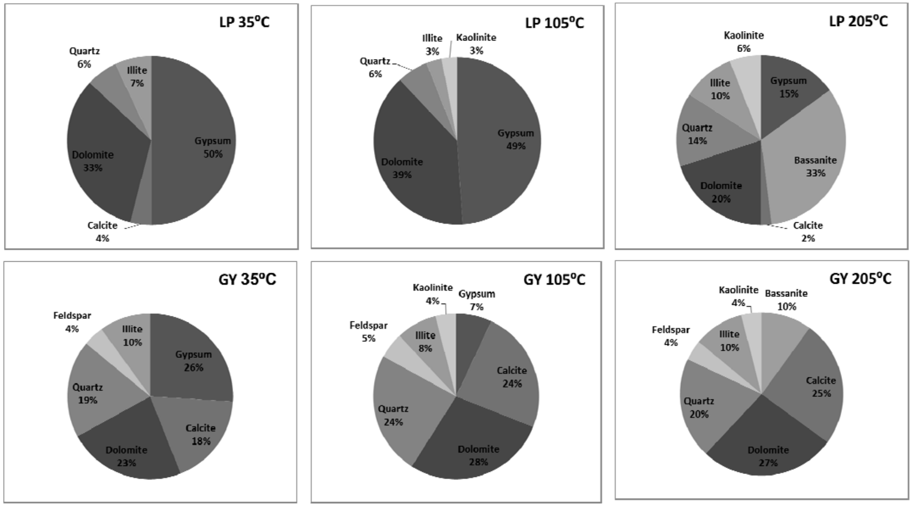

Fig. 4. Mineralogy of the soil (2 mm mesh). (LP) *Leptic Gypsisol* and (GY) *Haplic Gypsisol*.

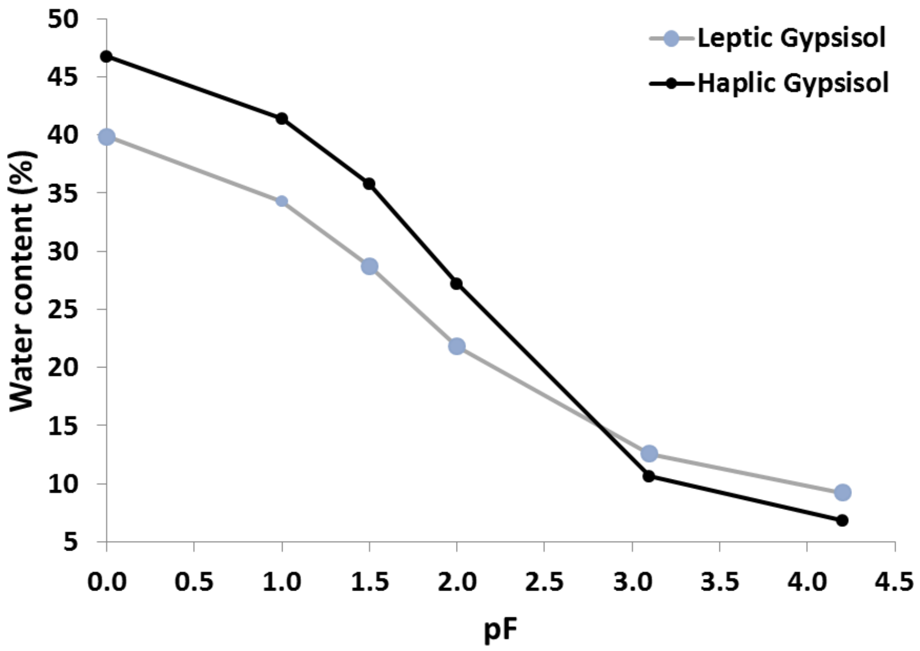

Fig. 5. Matric potential (*pF*) values at collected samples from the field. (LP) *Leptic Gypsisol* and (GY) *Haplic Gypsisol.*

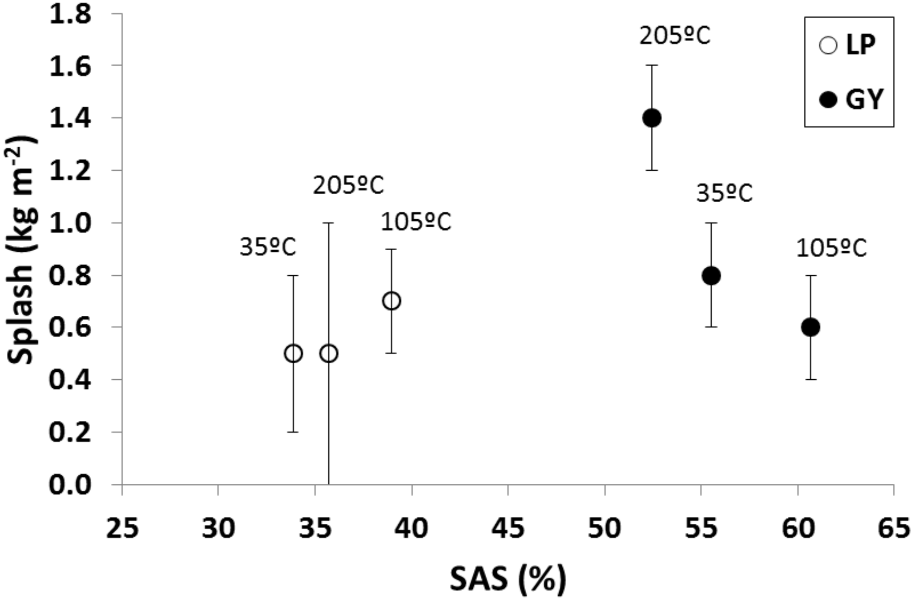

Fig. 6. Relationship between soil aggregate stability and splash erosion in both soils (means and standard deviations). (LP) *Leptic Gypsisol* and (GY)*Haplic Gypsisol.*

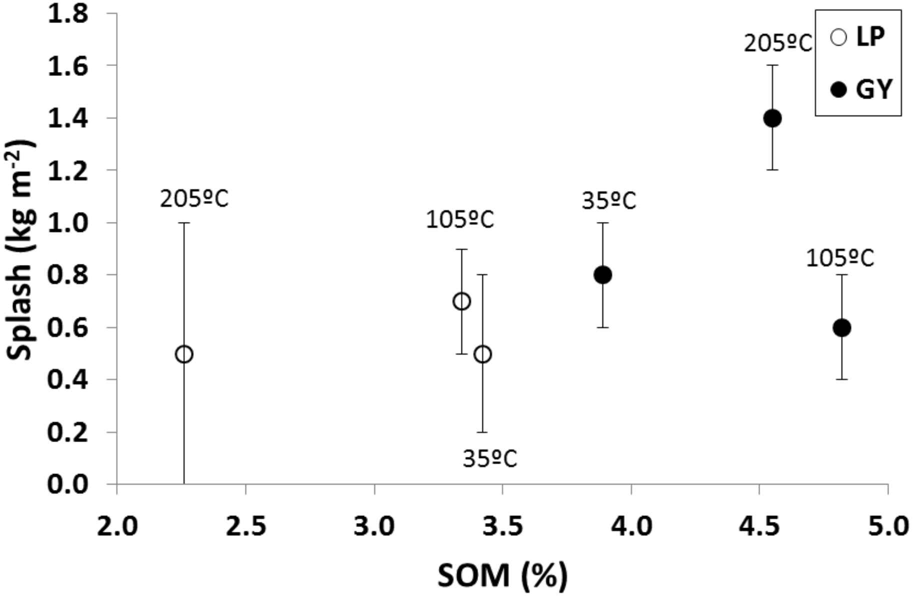

Fig. 7. Relationship between soil organic matter and splash erosion in both soils (means and standard deviations). (LP) *Leptic Gypsisol* and (GY)*Haplic Gypsisol.*