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Effects of a wildfire on rocks and soils in the Sarno Mountains, Campania, Southern Apennines

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RIASSUNTO

Effetti di un incendio boschivo su rocce e suoli nei Monti di Sarno, Campania, Appennino Meridionale.

Questo studio analizza i fenomeni di degradazione connessi ad un violento incendio boschivo che, il 4 agosto 2012, ha interessato un'area del versante meridionale dei Monti di Sarno. La descrizione degli stessi è stata possibile grazie ad un rilevamento di campagna realizzato subito dopo l'evento, che ha consentito di individuare le alterazioni delle rocce carbonatiche affioranti e dei suoli di copertura, costituiti in prevalenza da depositi vulcanoclastici pedogenizzati. Nel complesso, l'incendio ha incrementato la suscettibilità del versante nei confronti dei fenomeni erosivi di tipo idraulico connessi alle prime piogge autunnali, in quanto le alte temperature hanno ridotto la resistenza meccanica delle rocce ed hanno favorito la migrazione dei composti umici idrorepellenti all'interno del suolo. Tale situazione è stata notevolmente amplificata dalla mancata azione protettiva della copertura vegetale, che è stata quasi completamente distrutta dalle fiamme.

KEY WORDS: *Exfoliation, hydrophobic layer, Sarno, wildfire.*

INTRODUCTION

Every summer wildfires devastate large vegetated areas of Italy, especially in the mountainous and hilly slopes. From 1 January to 21 August 2012 the State Forestry Corps (CFS) have counted over 6345 fires, recording an increase of ca. 70% in the number of events along with the increase of the extent of burned areas in the order of 100%, compared to the same period of the 2011. The Salerno Province, in southern Italy, has been among the most severely affected by these phenomena. During the period from 14 to 21 August 2012 this area was struck by the highest number of wildfires of the whole region (CFS, 2012). Previous studies conducted in the Campania region, have demonstrated a correlation between wildfires and the increase of soil erosion and landslides (D'ARGENIO *et alii*, 2009; ORTOLANI, 2012). As a matter of fact, wildfires affect not only the biotic component of the ecosystem but also the rocks and the soil horizon. Particularly, the upper part of a soil is subject to chemical and physical alterations (KEELEY, 2009; SHAKESBY *et alii*, 2006). Modifications occurring in the upper horizons of the soil profile may have, in turn, dramatic effects on the hydraulic response of the slope, mostly in terms of water infiltration/runoff and/or soil erodibility, during major rainfall events which can occur after wildfires (CANNON *et alii*, 2005; MATAIX-SOLERA *et alii*, 2011). In this study we present the first results of a research conducted on the southern slope of the Sarno Mountains, in an area that was affected by a severe wildfire on the 4th August, 2012. In particular, we describe the effects of fire, which may favor subsequent erosion and runoff.

Fig. 1 – Overview of the burned area. In the background the landslides of May 1998 are indicated.

BACKGROUND

The study area (Fig. 1) is located on the southern edge of the Sarno Mts., representing one of the major morpho-structural units of the Southern Apennines. The area is well known for the many landslides that, in May 1998, caused 137 deaths, only in the city of Sarno (DEL PRETE *et alii*, 1998; CALCATERRA *et alii*, 1999; DE VITA, 2000; GUADAGNO, 2000; CASCINI, 2004).

The Sarno Mts. form an elevated mountain range (1131 m a.s.l.) cut by a system of bedrock rivers and channels characterized by relatively small catchment areas and pronounced disequilibrium of the stream profiles. The Pizzo d'Alvano ridge is mostly represented by a thick pile of Mesozoic carbonates covered by pyroclastic deposits originated from the volcanic districts of the Campi Flegrei and Somma-Vesuvius, interbedded with several soil horizons (DE VITA *et alii*, 2006).

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In the study area, the average slope angle is 35°, but even steeper inclinations can be measured at the head of thicker limestone strata that locally form a few meters thick sub-vertical escarpments very resistant to erosion (locally named "*pestelle*"). At places, stepped morphology is also recognized, as a likely result of the structural control exerted by the bedding attitudes of buried carbonate layers on the slope morphology.

The fire which occurred on August 4, 2012 affected an area of ca. 11 hectares (Fig. 1) with varying severity, mostly depending on the vegetation density, the slope morphology and the intensity of the winds feeding the flames during the wildfire events. The forest struck by fire was mainly represented by *quercus*, *cerro* and *roverella*, in association with other species such as *orniello*, *carpino nero* and *ontano napoletano*, along with various types of shrubs (IOVINO, 2007). The average thickness of the burned layer covering the rock substrate is in the order of 10 cm, as detected by comparison with adjacent areas unaffected by the fire.

FIRE EFFECTS

Field analysis permitted the identification of two main effects caused by the wildfire on the slopes, such as the exfoliation of the outcropping limestone rocks and the dramatic modification of the physical and chemical properties of the soil. Exfoliation processes (Fig. 2) mostly consists in a surface mechanical degradation of the carbonate bedrock, during the contact with fire, producing accelerated thermoclastism. It is known, in fact, that the temperature in the flame interiors during a forest fire may reach values up to 850° C at the soil - litter contact (DUNN & DEBANO, 1977), or even 1100° C within the plant canopy, depending on the burning mass and the rate of fire propagation (COUNTRYMAN, 1964). In the case of carbonate bedrocks, the heat produced by the flames causes a rapid thermal dilatation of the crystalline network of the calcite at the rock surface, while during the cooling phase after the end of the fire, the crystalline structure undergoes a significant contraction thus determining the fracturing of the rock surface. This is in turn the cause for the detachment of rock fragments and exfoliation of rock "chips" ca. 5-10 mm thick, often displaying lenticular shape and angular contours (ZIMMERMANN *et alii*, 1994). Detached fragments may form immediately after the fire or even after weeks or months (BALLAIS *et alii*, 1994), depending on the local intensity of erosional agents such as rain and wind. Our field observations showed that the degree of exfoliation of the carbonate bedrock may vary locally, depending on the slope morphology and/or the actual location of the outcrop within the area struck by the wildfire. For example, the evidence of the most severe effects caused by the fire appear to be concentrated along the major escarpments occurring along the slope, suggesting that nearly-vertical slope-brakes likely act as natural barrier were flames are "forced" to remain longer in contact with the bedrock.

Fig. 2 – Limestone bedrock showing fire-induced exfoliation in the outcrop.

Fig. 3 – Exploratory trench showing the hydrophobic layer (yellow dashed line) located at a depth of ca. 5 cm from the surface. Lower insert shows a droplet used for WDP test, remaining in a fixed position and unabsorbed for

A further impact of wildfire is the evidence of a "thermal gradient" along a vertical section of the burned soil down to a depth of several centimeters from the ground surface. Because of the litter combustion, part of the organic matter contained in the soil, including humic acids, is transformed into high-temperature fluids. These fluids are partly released into the atmosphere and are partly infiltrated into the soil, and becomes condensed down to a depth were temperatures are lower

(DEBANO, 1981).

The process typically creates a hydrophobic layer 1-2 cm in thickness at a depth of 5-6 cm within the soil (Fig. 3). These features can be detected by small excavations and water drop penetration (WDP) tests (DEBANO, 1981). Several WDP tests conducted in the burned soil of study area have produced droplets remaining in a fixed position and unabsorbed for more than 30 min at a depth of 5-6 cm from the surface, thus indicating severe water-repellent conditions within the soil (BISDOM *et alii* 1993).

DISCUSSION AND CONCLUSIONS

The study documents a series of accelerated degradation processes that may affect the stability of mountain slopes after wildfires, based on field examples from the Sarno Mts., Campania, Southern Apennines. In the study area a forest fire of medium-high severity caused severe thermal stress to both the carbonate rock surfaces and the soil upper horizon. Among the major effects of the wildfire event there are the surficial fracturing of the rocks (exfoliation) and the formation of a hydrophobic layer at a depth of ca. 5 cm within the soil. The almost complete destruction of the deciduous forest following the wildfire caused a dramatic exposure of the slopes in the study area thus creating favorable conditions for accelerated erosion. The results of our research work suggest that these phenomena can be extremely active after major rainfall events following severe fires, particularly where loose pyroclastic deposits cover a carbonate bedrock, as also documented by the historic flood of the Amalfi Coast, which took place on October 25, 1954 (ESPOSITO *et alii*, 2004).

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