# Runoff at the micro-plot and slope scale following wildfire, central Portugal

D.C.S. Vieira[a*], J.J. Keizer[a], J.P. Nunes[a], I.A.C. Fernandes[a], S.R. Faria[a], R.S.V. Ferreira[a], E.T. Pedrosa[a], M.E.T. Varela[a], L.M.G. Pereira[b]

a. Centre for Environmental and Marine Studies (CESAM), Dpt. Environment, U. Aveiro, 3810-193 Aveiro (Portugal); b. Águeda Higher School of Technology and Management (ESTGA), U.Aveiro, 3750-127 Águeda
*dianac.s.vieira@ua.pt

## Introduction

Through their effects on soil properties and vegetation/litter cover, wildfires can strongly enhance overland flow generation and accelerate soil erosion [1] and, thereby, negatively affect land-use sustainability as well as downstream aquatic and flood zones. Wildfires are a common phenomenon in present-day Portugal, devastating in an average year some 100.000 ha of forest and woodlands and in an exceptional year like 2003 over 400.000 ha. There therefore exists a clear need in Portugal for a tool that can provide guidance to post-fire land management by predicting soil erosion risk, on the one hand, and, on the other, the mitigation effectiveness of soil conservation measures. Such a tool has recently been developed for the Western U.S.A. [3: ERMiT] but its suitability for Portuguese forests will need to be corroborated by field observations.

Testing the suitability of existing erosion models in recently burned forest areas in Portugal is, in a nutshell, the aim of the EROSFIRE projects. In the first EROSFIRE project the emphasis was on the prediction of erosion at the scale of individual hill slopes. In the ongoing EROSFIRE-II project the spatial scope is extended to include the catchment scale, so that also the connectivity between hill slopes as well as channel and road processes are being addressed. Besides ERMiT, the principal models under evaluation for slope-scale erosion prediction are: (i) the variant of USLE [4] applied by the Portuguese Water Institute after the wildfires of 2003; (ii) the Morgan–Morgan–Finney model (MMF) [5]; (iii) MEFIDIS [6]. From these models, MEFIDIS and perhaps MMF will, after successful calibration at the slope scale, also be applied for predicting catchment-scale sediment yields of extreme events.

## Objectives

This presentation will concern the runoff/erosion measurements by the EROSFIRE-II project in a recently burned area nearby the Colmeal village, central Portugal. These measurements serve two overall purposes: (i) to validate the slope-scale erosion modelling results obtained by the precursor project in other recently burned areas; (ii) to scale-up these modelling results to the Colmeal catchment and assess them against the losses during selected storms.

The extensive data set from the Colmeal area, however, has not yet been thoroughly analysed. The present work intends to make a step in that direction but will necessarily be limited to the overland flow data from the micro-plots and slope-scale plots from two selected hill slopes.

## Study area

On August 28 2008, a forest area of about 70 ha burned near to the village of Colmeal, municipality of Góis, central Portugal (Figure 1). The burned area comprised three catchments, two of which were only burned to a small extent. Therefore, the third, entirely burned catchment was selected for the installation of a hydrometric gauging station as well as for the installation of the bulk of the erosion plots.

Prior to the wildfire, the study area was covered by commercial forest plantations of eucalypt (*Eucalyptus globulus*) and, to a lesser extent, Maritime Pine (*Pinus pinaster*). In some of the valleys within the area, there are evidences of prior agricultural land use in the form of abandoned terrace walls. Post-fire forestry operations involved logging as well as terracing

(as clearly visible in Figure 1 in the upper part of the central catchment) but parts of the area continue without intervention.
The soils in the area are shallow and overlay pre-Ordovician schists. They can be classified as Leptosols or, under local conditions favouring greater profile development, Cambisols. The climate can be characterised as humid meso-thermal, with a prolonged dry and warm summer. The mean annual temperature and precipitation are about 12 °C and 1500 mm.

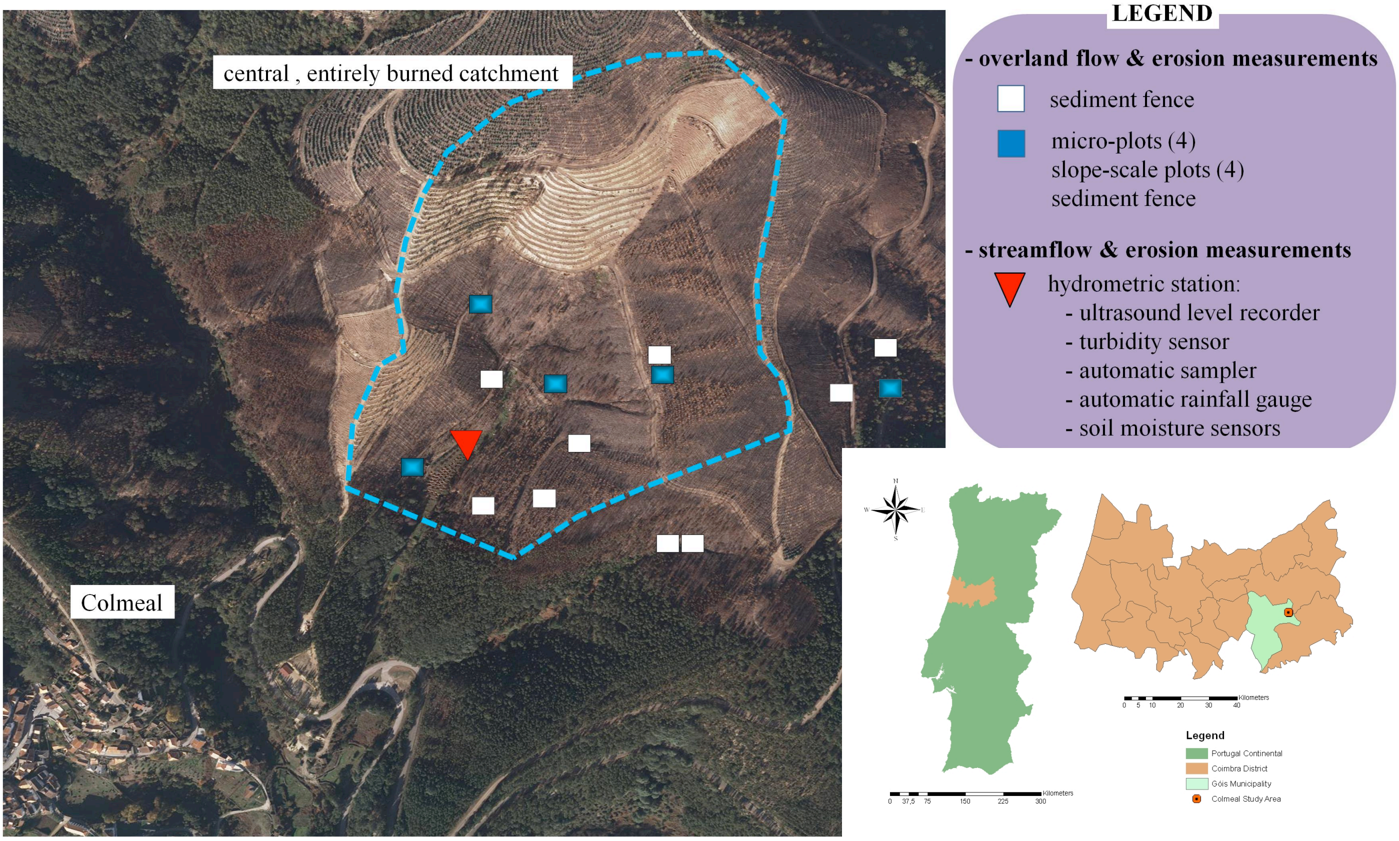

Figure 1. Location and instrumentation of the Colmeal study area..

## Methodology

By December 1 2008, the central burned catchment was instrumented with an H-flume and a automatic gauging station composed of a data logger, a rainfall gauge, a water level sensor, a turbidity sensor and an automatic sampler. The remaining devices for erosion measurements (sediment fences and runoff-erosion plots) as well as various automatic and totaliser rainfall gauges were installed much earlier, i.e. within one month after the fire and before any significant rainfall. A total of 11 slopes and 4 valleys were equipped with sediment fences. Five of these slopes were further equipped with each 4 bounded micro-plots and 4 unbounded, slope-scale plots, as is illustrated by Figure 2. The plots are linked up with tanks of 30 to 60 L, in which the overland flow is collected. The contributing areas of the bounded plots vary between 0.25-0.50 $m^2$, whereas those of the unbounded plots are estimated to range from 25 to 50 $m^2$ and those of the sediment fences from 100 to 200 $m^2$. The current estimates of the contributing areas of the open plots and sediment fences are obtained by multiplying the width of the plots/fences with the slope length measured in the field. More comprehensive estimates are going to be derived from the results of a topographic survey by terrestrial laser scanning as well as from a high-resolution Digital Terrain Model that was obtained from digital aerial photography from a dedicated flight mission.

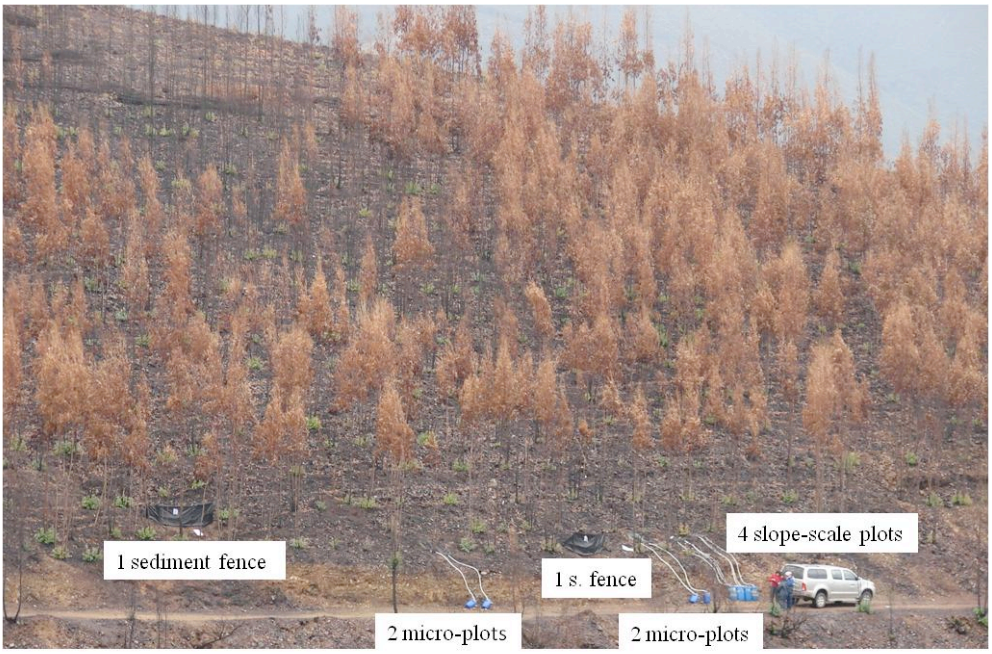

Figure 2. Instrumentation at one of the study slopes in the Colmeal study area.

The plots have been (and continue to be) monitored on a weekly basis or, in the absence of rainfall, a fortnightly basis. This encompasses the measurement of the runoff collected in the tanks and the gathering of a runoff sample in each tank. The sediment and organic matter concentrations of these samples are being analyzed in the laboratory using standard methods. The sediment fences have been emptied at irregular intervals, depending on the accumulation of sediments as well as on weather conditions. The moisture and organic matter contents of the sediment fence samples is being determined by standard laboratory procedures.

Ancillary data that have been collected include: continuous recordings as well as monthly measurements of soil moisture content; monthly measurements of soil water repellency, and regular measurements of ground cover.

## Results and Discussion

At the two slopes selected for the present analysis, the runoff coefficients are markedly higher for the micro-plots than for the slope-scale plots. The average values over the first year following the wildfire range from 1 to 5 % and from 15 to 45 %, respectively. Nonetheless, there exists a broad agreement in the temporal patterns of overland flow generation at the two scales. This is illustrated in Figure 3 for one of the slopes. A possible explanation for the differences in overland flow at the two spatial scales is that the contributing areas of the slope-scale plots are much smaller than estimated here (as plot width x slope length). Alternatively, spatial heterogeneity in soil surface and/or topsoil properties could result in increasing opportunities for runoff to infiltrate at greater plot sizes (see [1]). Worth noting is that also the Açores1/2 sites of the EROSFIRE project revealed higher runoff coefficients for bounded micro-plots ([7]: 20-25 %) than for unbounded slope-scale plots ([8]: 1-2 %).

At both plot scales, the runoff coefficients differ in a consistent manner between the two slopes. The higher values at slope 3 than slope 8 cannot be attributed to differences in slope angle, since slope angles are basically the same (27 and 29$^o$, respectively). Land use could play a role, with slope 8 corresponding to a ploughed eucalypt plantation and slope 3 to an unploughed Maritime Pine stand. The above-mentioned Açores1 and 2 sites also differed little in micro-plot and slope-scale runoff coefficients, notwithstanding the fact that the former had been ploughed and the latter not. In the case of the Açores as well as the present study sites, the limited impact of ploughing probably reflects its timing, having taken place well before the wildfire instead of after it.

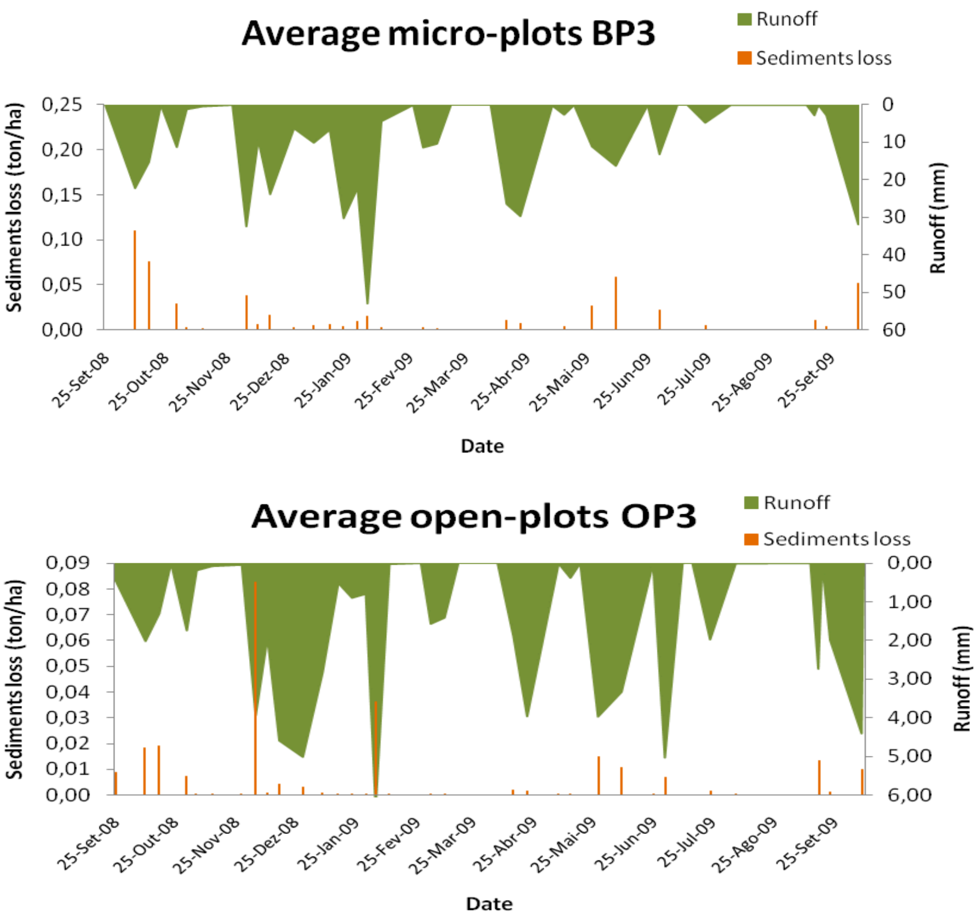

Figure 2. Overland flow and sediment losses during the first year after wildfire at the scale of micro-plots as well as slope-scale plots at one of the study sites in the Colmeal study area

## References

1. Shakesby RA, Doerr SH, 2006. Wildfire as a hydrological and geomorphological agent. Earth-Science Reviews 74:269-307.

2. Pereira J., Carreira J. Silva J., Vasconcelos M., 2005. Alguns conceitos basicos sobre os fogos rurais em Portugal. In: Pereira J.S., Pereira J.M.C. et al.(eds.), *Incêndios florestais em Portugal* 886 – *caracterização, impactes e prevenção*, pg 133-16, ISAPress, Lisbon.

3. Robichaud P.R., Elliot W.J., Pierson F.B., Hall D.E., Moffet C.A., 2007. Predicting postfire erosion and mitigation effectiveness with a web-based probabilistic erosion model. *Catena*. 71: 229-241.

4. Wischmeier W H, Smith D D.1978. Predicting rainfall-erosion losses- a guide to conservation planning. Agriculture Handbook. Nº537. USDA. Washington, D.C; 58.

5. Morgan R P C. 2001. A simple approach to soil loss prediction: a revised MMF model. *Catena* **44**: 305–322.

6. Nunes J.P., Vieira G.N., Seixas J., Gonçalves P., Carvalhais N., 2005. Evaluating the MEFIDIS model for runoff and soil erosion prediction during rainfall events. *Catena* 61 (2-3): 210-228

7. Malvar M.C.. Prats S.A., Nunes J.P., Keizer J.J., 2008. Micro-plot scale overland flow generation and soil erosion in two recently burnt eucalypt stands in north-central Portugal. In: Proc.s 15th International Congress of ISCO (Budapest, 18-23/05/2008) (CD).

8. Keizer J.J., Nunes J.P., Palacios E., Beekman W., Malvar M.C., Prats S.A., Ferreira R.S.V., Varela, M.E., 2008. Soil erosion modeling for two recently burnt eucalypt slopes. In: Procs. 15th International Congress of ISCO (Budapest, 18-23/05/2008) (CD).