Tracking bedload origin following an extreme event in a burned catchment in central Portugal.

C.O.A. Coelho [1], A.J.D. Ferreira[1,2], F.P. Lopes [1] and A.K. Boulet [1]

[1] CESAM, Departamento de Ambiente e Ordenamento, Universidade de Aveiro, P-3810-193 Aveiro Portugal. coelho@dao.ua.pt

[2] CERNAS, Environmental Technology Sector, Department of Pure and Environment Sciences, Escola Superior Agrária de Coimbra, Bencanta, P-3040-316 Coimbra, Portugal aferreira@esac.pt

Abstract:
This paper addressees the problem of bedload transport during extreme rainfall events. Following two wildland fires in five years in a small catchment located in central-south Portugal, and an extreme rainfall event, with 27 mm in 40 minutes, a massive overland flow and runoff response occurred, that mobilized unprecedented amounts of bedload material, that exceeded 2.3m^3 per hectare. Field observation showed that only a small part of the catchment contributed to the sediment loss, through mobilization of material that was already in the stream channel, through bank erosion and collapse, rill and gully formation, terrace collapse and in some places, direct contribution of slope overland flow to the stream channel.

Résumé:
Cet article concerne le problème du transport des sédiments au fond des rivières au cours d'événements pluvieux extrêmes. Suite à 2 incendies en 5 ans, dans un petit bassin hydrographique situé au centre-sud du Portugal, un événement pluvieux extrême, de 27mm en 40 minutes, a entraîné une réponse massive en terme de ruissellement superficiel et de l'écoulement des rivières qui a mobilisé des quantités sans précédent de matériel de fond de rivière, qui dépassèrent les 2.3m^3 par hectare. Les observations sur le terrain ont montré que seule une petite partie du bassin hydrographique avait contribué à la perte en sédiments, par la mobilisation de matériel qui se trouvait déjà dans le canal de la rivière, par une érosion des rives, par la formation de ravines et crevasses, l'écroulement de terrasses et par certains endroits, la contribution directe du ruissellement superficielle vers le canal de la rivière.

Introduction:
This study addresses bedload transport processes following an extreme event in the Caratão catchment (61ha) burned twice in the previous 5 years by wildland fires. Forest fires are known to enhance overland flow (Shakesby et al. 2000, Coelho et al. 2004, Ferreira et al. 2005a, Ferreira et al. 2005b), catchment runoff and sediment and solute yield, although few works report an influence over bedload transport (Robichaud 2005). Soil and vegetation changes induced by forest fires have a wider impact than the depletion of the ash layer. The absence of obstacles and sinks to water progression, and down slope cumulative effect of overland flow, increases the hazard of flash floods and sediment bed load transport in small burned catchments.
This work presents evidence that the high soil water repellency that enhances overland flow, the absence of obstacles to the progression of surface water fluxes, and the occurrence of extreme

rainfall events were responsible for unusually high overland flow amounts, able to transfer sediments of some magnitude from the slopes to the stream channel and transport of those sediments down the stream channel.

Study area:
The catchment is located in the Mação Municipality, in the lower Tejo river basin, in Central Portugal. With an annual rainfall in the 800 – 1000 mm range, the area is affected by a relatively long dry summer period that can last for 5/6 months. The underlying lithology is schist and Grauwacke, and the soils are poorly developed humic cambisols. The catchment, is covered by small terraces, witnesses of a intense human occupation until the middle of the twentieth century. The catchment was then afforested with *Pinus pinaster*, and burned a first time in 1998. The recovering sparse vegetation was burned a second time in the catastrophic 2003 fires, leaving the soil with no vegetation or litter layer and a strong water repellence character.

Materials and methods:
During the period between the two forest fires, the catchment was instrumented with a OTT – Thalimedes water level recorder, a bedload trapping pool, a weir and an automatic rainfall gauge. The extreme event destroyed the water level recorder. This is the reason why peak flow was estimated by the manning-Stricker formula. Bedload amount was assessed due to the formation of a natural dam made of trunks, during the rainfall event that trapped a big percentage, although not all bedload mobilized materials.

Results and discussion:
The inexistence of any barriers to the progression of overland flow implies that the ashes and sediments are easily transported to the channel and exit the catchment. Nevertheless, then amounts of runoff and bedload transported after the first forest fire (figure 1 and figure 2) are negligible when compared with the extreme event in November 2003. In fact, the few obstacles that remained after the first fire were completely burned down after the second fire, reducing the resistance to water progression, and the precipitation of 27mm of rainfall in 40 minutes lead to the reach of several processes thresholds, and originated several unusual sediment sources. In fact, it was estimated, using the Manning-Stricker formula that the peak flow reached between 4 and 8 $m^3.s^{-1}$ (previous peaks didn't exceed $1m^3.s^{-1}$), originating the transport of $145m^3$ of sediment (figure 1 and figure 2). This represents a loss of more than $2.3m^3$ of sediment per hectare in a single event. These values do not include the losses dissolved or suspended in the runoff during the event. Furthermore, these sediments were loss in one single event. Previous or subsequent events were not taken into consideration. The total amount of materials lost are expected to have been much higher, adding the dissolved and suspended materials and other events.
The question remains on where the sediments came through, since no significant bedload mobilization was observed (less than 0.5m3) in the five years following the first forest fire. In addition, some of the mobilized boulders weighed more than 30 Kg.
A field survey, immediately after the extreme rainfall event shown that several processes were in the origin of the incredible amount of mobilized material. Several sources were identified, and it became apparent that the source area was only a small percentage of the entire catchment area. Large areas didn't contribute to the sediment yield, and large undisturbed slopes, not directly linked

to the stream channel due to slope angle ruptures at the basis, did not presented a significant accumulation of sediments at the slope basis.

Amongst the identified bedload material source we can quote:

(1) Mobilization of materials already in the stream channel.
(2) Stream bank erosion and collapse
(3) Rill and gully formation;
(4) Terraces collapse.
(5) Direct overland flow contribution to the stream channel in areas with rectilinear slopes that where slope do not present a slope angle rupture before the channel.

Figure 1 - Peak size vrs. rainfall amount

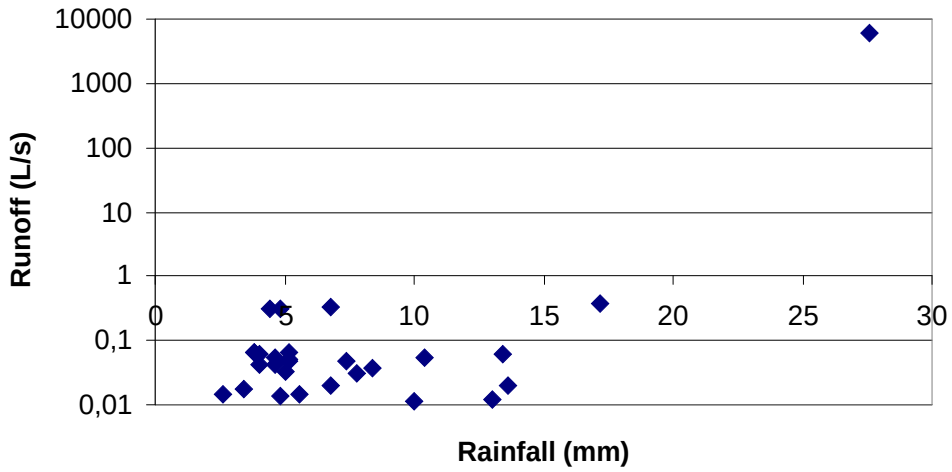
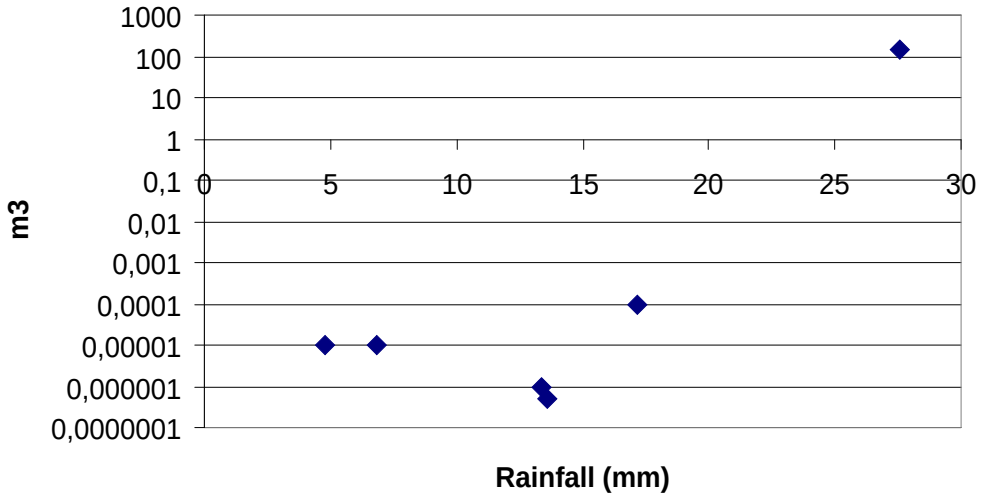


Figure 2 - Bedload transport



Conclusion

This work discusses the changes on soil characteristics, including soil water repellence spatial distribution and severity. Furthermore, the paper discusses the impact of forest fires on flash flood production and beadload transport in small burned catchments, providing an explanation for bedload sediment source during extreme rainfall events. Identified sediment sources are bank erosion and collapse, rill and gully formation, terrace collapse and in some places laminar overland flow, especially in areas where there is a continuity between the slope and the stream channel.

References:

Coelho, C.O.A, Ferreira, A.J.D., Boulet, AK, Keizer, J.J. (2004) Overland flow generation processes, erosion yields and solute loss following different intensity fires. *Quarterly Journal Of Engineering Geology & Hydrogeology*, **37**, 233-240

Ferreira, A.J.D., Coelho, C.O.A., Boulet, A.K., Leighton-Boyce, G., Keizer, J.J. & Ritsema, C.J. (2005a), Influence of burning intensity on water repellence and hydrological processes at forest sites in Portugal. *Australian Journal of Soil Research* **43** (3) 327-336

Ferreira A.J.D., Coelho, C.O.A. Boulet; A.K. and F. P. Lopes (2005b) Temporal patterns of solute loss following wildfires in Central Portugal. *International Journal of Wildland Fire*, **14** (4) (in press).

Robichaud, P.R. (2005) Measurement of postfire hillslope erosion to evaluate and model rehabilitation treatment effectiveness and recovery. *International Journal of Wildland Fire*, **14** (4) (in press).