Logging of Burned Pines and Rill Erosion in Mediterranean Drylands

Angeles Garcia Mayor, Researcher, University of Alicante, Departamento de Ecologia coneo 99, Alicante 03080, SPAIN, TEL: 01-(34)-627-68-93-43, FAX: 01-(34)-96-590-3625, EMAIL: amayor@tucson.ars.ag.gov

Susana Bautista, Fundación CEAM. C/Charles Darwin, 14. e-46980 Paterna. Spain

Teresa Gimeno, Departamento de Ecologia, Universidad de Alicante. Apdo. 99. E-03080 alicante, Spain

ABSTRACT

We studied the consequences of post-fire logging on rill erosion in six burnt dryland forests in eastern Spain. We selected a range of environmental conditions in order to gain in representativeness for analyzing treatment effect. The experimental sites varied in dominant pine species *Pinus halepensis* and *Pinus pinaster*, bedrock and soil types, geomorphic conditions, and stand characteristics such as pine density. Within each site, we selected one representative slope and we measured the number and size of all the rills in the selected slope. Savage logging promoted large-scale deep-rill erosion in most of the study sites. The severity of the effects depended mainly on the slope length, density of logged pines and the type of substrate, with soils developed over sandstone showing the highest soil loss values by rill erosion, which ranged between 10.5 and 51.2 Mg ha^{-1} $year^{-1}$ along the first three years after logging.

INTRODUCTION

Forest fires are very common in Mediterranean woodlands. Recent landuse changes in these woodlands resulted in the development of continuous highly inflammable forest areas (Moreno et al., 1998; Vallejo & Alloza, 1998), leading to an increase in fire incidence (Pausas & Vallejo, 1999). Wildfires remove the plant cover and litter layer, which play a major role in the prevention of soil erosion caused by raindrop impact and overland flow. Thus, the risk of soil degradation is very high immediately after a fire and decreases with time as the plant cover regenerates (e.g. Wells, 1981). Fire can also increase soil vulnerability to erosion processes by altering soil physical and chemical properties (Soto *et al*., 1991; DeBano *et al*., 1998). In addition, heavy rainfalls commonly follow most of Mediterranean wildfires during autumn, when vegetation cover is still very low. These conditions are favorable to degradation and soil losses (Llovet *et al*., 1996). Mediterranean drylands represent an intersection of fire-prone and desertification-prone areas (Pérez-Trejo, 1994; Vallejo & Alloza, 1998) and, due to their particularly slow plant recovery after disturbances (Pausas *et al*., 1999), they are thought to be threatened by post-fire land degradation.

Logging activities after forest fires are very common in Mediterranean woodlands. Due to the potential vulnerability of soils in burned areas, savage logging after a forest fire is expected to increase soil erosion risk. However, despite the extent of areas managed with this post-fire treatment there is a lack of information on its impacts on soils. Since plant recovery is strongly constrained as a consequence of water scarcity, soil disturbance due to post-fire logging is expected to be particularly severe in drylands. In this work we studied the effects of post-fire

logging on rill erosion in Mediterranean drylands. The problem has been studied in an extensive way, analyzing a range of common environmental conditions in these areas.

METHODS

We selected 4 *Pinus pinaster* and 2 *Pinus halepensis* burnt forest in the Region of Valencia, in eastern Spain (Figure 1). The study sites varied in environmental conditions and stand characteristics such as pine density and basal area (Table 1). Climate is dry Mediterranean, with mean annual rainfall ranging from 350 to 600 mm. Slopes ranged from 20 to 45% and elevations ranged from 730 to 1350 m above sea level. The sites were studied 2-3 years after post-fire logging, which was applied 0.5-1.5 years after the wildfires. Dragging of logs was made with mules and charred wood debris were left *in situ* or removed depending on the sites (Table 1). At the sampling time, post-fire vegetation in the study sites consisted in fire-prone shrublands dominated by *Cistus* species, legume shrubs and perennial grasses.

One representative slope was selected within each site and the number and size of all the rills in the selected slopes were measured. We established a minimum of ten transversal transects along each rill and we measured rill depth at 20 cm intervals along these transects (Figure 1). For each rill, volume of soil loss was estimated by numeric integration after interpolation of depth measurements. Rill erosion rates were estimated from soil volume and bulk density data. Percentage of slope affected by rills was estimated by photography and image analysis. In order to characterize the burnt pine stands, basal area and pine density were determined for each site.

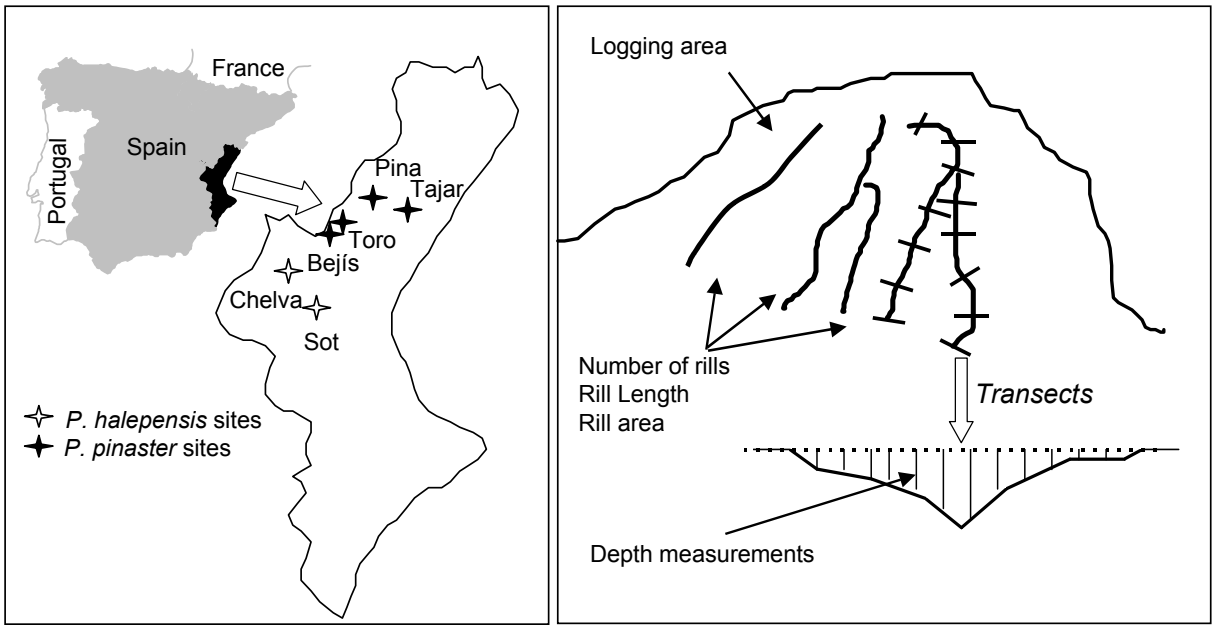

Figure 1. Location of the study sites (left) and scheme of the procedure for the quantification of rill erosion losses in the study sites (right).

RESULTS

In four of the six study sites, post-fire logging caused rill erosion, with soil loss ranging between 7.0 and 51.2 tons per hectare and year (Table 1). The most severe rill erosion was observed in Toro site, which combined sandy soils developed over sandstone with high values of pine density and basal area. Most of the rills of the study sites did not show evidences of recovery, even showed clear signs –absence of plant cover, freshly eroded or settled matter– of slow growth.

Slope length and density of logged pines showed the best relationships with rill erosion rates (Figure 2). Mean annual precipitation, slope gradient, and basal area (data not shown) did not significantly explain the erosion rates observed.

Table 1. Main characteristics of the study sites and soil loss rates by rill erosion.

Study site	Charred-wood debris	Log density (trees ha^{-1})	Basal area ($cm^2\ m^{-2}$)	Bedrock	Soil loss per rill area ($Kg\ m^{-2}\ y^{-1}$)	Soil loss rate ($Mg\ ha^{-1}\ y^{-1}$)
Pinus pinaster sites						
Toro	Piled up + chopped	1060	34.2 ± 4.4	Sandstone	37.1	51.2
Bejís	Left *in situ*	918	12.0 ± 0.1	Sandstone	18.1	10.5
Pina	Piled up + burnt	312	13.5 ± 1.9	Sandstone	_	_
Tajar	Chopped + spread on log slides	744	27.5 ± 0.1	Sandstone	_	_
Pinus halepensis sites						
Sot	Left *in situ*	358	20.7 ± 7.5	Marl-limestone	8.9	7.0
Chelva	Left *in situ*	444	14.3 ± 6.3	Marl-limestone	10.8	7.9

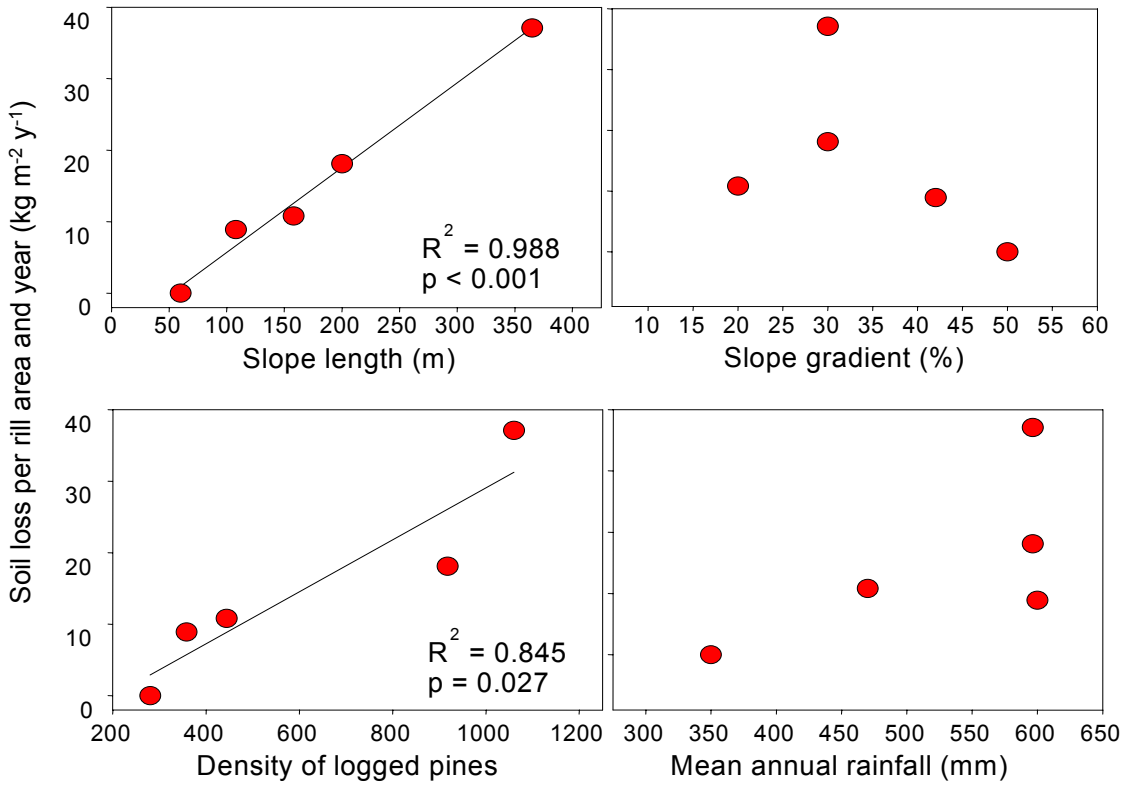

Figure 2. Relationships between rill erosion rates and site characteristics

DISCUSSION

Common post-fire logging practices promoted severe rill erosion in most of the study areas. The results indicate that there is a moderate to high risk of rill erosion associated to this post-fire management in forest drylands in eastern Spain. It is interesting to note that in one of the sites with no signs of rill erosion, Tajar, the chopped wood debris were spread over the log slides. This conservation measure acted as a mulching treatment and probably protected loose post-logging soils from rainfall and runoff impact (Shakesby *et al*., 1994; Bautista *et al*., 1996).

Our results showed that rill erosion processes may greatly vary with environmental variables, highlighting that a general assessment of the consequences of post-fire logging on rill erosion must be done from different conditions. Rill erosion severity mainly depended on slope length and density of logged pines, probably due to greater accumulation of burned logs for dragging along the same slide as the slope length and the number of pines increases. Thus, the site combining the lowest values of these variables, Pina site, did not show any evidence of rill erosion processes. Soils developed over sandstone resulted more vulnerable to post-fire logging than those developed over limestone. In our study area, sandy soils developed over sandstone are commonly poorly structured and highly erodible (Andreu *et al*., 1994). Other

variables commonly related to soil erosion such as slope gradient or annual rainfall had no effect on logging-dependent rill erosion. In sum, in Mediterranean drylands, severe savage logging, characterized by long log slides and high log density, is associated to moderate and severe rill erosion, with the degree of damage depending on soil vulnerability.

ACKNOWLEDGMENTS

This work was supported by SPREAD (EVG1-2001-00027) research project, funded by the European Commission. CEAM Foundation is supported by the Regional Government of Valencia (*Generalitat Valenciana*) and Fundación Bancaixa.

REFERENCES

Andreu, V., Rubio, J.L., Forteza, J. & Cerni, R., 1994. Postfire effects on soil quality and nutrient losses. In: Proceedings 2nd International Conference on Forest Fire Research, vol II, p. 1241-1250. November 1994, Coimbra.

Bautista, S., Bellot, J. & Vallejo, V.R., 1996. Mulching treatment for postfire soil conservation in a semiarid ecosystem. Arid Soil Research and Rehabilitation, 10: 235-242.

DeBano, L.F., Neary, D.G. & P.F. Ffolliott, 1998. Fire's effects on ecosystems. John Wiley & Sons. New York.

Llovet, J., Bautista, S. & V.R. Vallejo, 1996. Soil surface compaction dynamics in burnt areas. International Conference on Land Degradation. 10-14 June 1996. Adana, Turkey.

Moreno, J.M., Vázquez, A. and Vélez, R., 1998. Recent history of forest fires in Spain. In: J.M. Moreno (ed.), Large forest fires, p. 159-185. Backhuys Pub., Leiden, The Netherlands.

Pausas, J.G. & Vallejo, V.R., 1999. The role of fire in European Mediterranean ecosystems. In: Chuvieco E. (ed.), Remote sensing of large wildfires in the European Mediterranean basin, p. 3-16. Springer-Verlag

Pausas, J.G., Carbo. E., Caturla, R.N., Gil, J.M. & V.R. Vallejo, 1999. Post-fire regeneration patterns in the eastern Iberian Peninsula. Acta Oecologica 20: 499-508.
Pérez-Trejo, F., 1994. Desertification and land degradation in the European Mediterranean. European Commission, DG XII. Luxembourg.

Shakesby, R.A., Boakes, D.J., Coelho, C.O.A., Gonçalves, A.J.B. & Walsh, R.P.D., 1994. Limiting soil loss after forest fire in Portugal: The influence of different post-fire timber clearance practices. In: Proceedings 2nd International Conference on Forest Fire Research, vol II, p. 1161-1170. November 1994, Coimbra.

Soto, B., Benito, E. & Díaz-Fierros, F., 1991. Heat-induced degradation processes in forest soils. Int. J. Wildland Fire, 1(3): 147-152.

Vallejo, R. & Alloza, J.A., 1998. The restoration of burned lands: The case of eastern Spain. J.M. Moreno (ed.), Large forest fires, p. 91-108. Backhuys Publishers, Leiden.

Wells, W.G., II, 1981. Some effects of brush fires on erosion processes in coastal Southern California. In: T.R.H. Davies y A.J. Pearce, eds., Erosion and sediment transport in Pacific Rim steeplands (Christchurch, 1981), p. 305-342. IAHS Publication No. 132.