Fuel reduction treatments influence on soil erosion

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Summary

A study was conducted in a shrubland (low-mixed heathland) area in Pontevedra province (Galicia, NW Spain) to analize the influence of fuel reduction treatments on runoff and soil erosion. A randomized block design was used with three different treatments: prescribed burning, shrub chopping, and shrub clearing and extraction. The treatments were made in May 2006.

The simulations were carried out immediately after treatments application and before any appreciable rainfall was measured. 12 simulation experiments in each treatment were developed.

A rainfall simulator was used to apply rainfall for 30 minutes. A rainfall rate of 67 $mm.h^{-1}$ was applied to each runoff plot (1 m^2). Runoff samples were analysed for runoff volume and sediment concentration drying at 105ºC, and weighing each sample. Before each simulation estimation of soil organic cover were made.
No statistically significant differences in accumulated runoff were found between treatments. Prescribed burning yielded the highest soil erosion losses (248 $kg.ha^{-1}$), statistically greater than the other two treatments although soil losses were low in all the cases.

Introduction

Shrub communities cover in Galicia more than a half of its total territory (Min. Med. Amb, 2001). Most of these areas are mainly covered by different gorse species usually dominated by *Ulex europaeus*. In these shrubland areas fuel loadings of 40-50 Mg ha^{-1} are common (Casal and others, 1990; Vega and others, 2001). Over the last 11 years, 10,245 ± 1,874 fires have burned anually destroying 19,000 ± 6,828 ha of shrubland areas (Min. Med. Amb., 2002). Prescribed burning, alone or combined with other techniques, is currently used as an effective and economic tool for wildfire hazard reduction.

Increases in runoff and erosion after shrub burning have been measured in different shrubland-type ecosystems (Marcos and others, 2000; Gimeno and others, 2000; Soto and Díaz-Fierros,1998; De Luis and others, 2003; Vega and others, 2005). However, the consequences on runoff and erosion of other fuel management treatments are poorly known

Forest vegetation and forest floor (litter + duff) protect the mineral soil from raindrop impact. Forest floor can absorb and storage most part of the rainfall and regulate soil infiltration capacity (Martin and Moody, 2001). Fuel management activities alter evapotranspiration rates and can disturb the soil and its infiltration capacity, thus enhancing runoff

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The aim of this study was to quantify possible differences in infiltration rates and erosion yield due to different fuel management techniques in shrublands and to identify the main variables influencing those possible changes.

Materials and methods

Study site

This study was carried out in Dozón (Pontevedra; N.W. Spain; 42º 35' 8'' N; 8º 5' 49'' W). The mean elevation of the research area is 600 m a.s.l.. The average annual precipitation is 1600 mm and the mean annual temperature is 12.5 ºC. Vegetation is a mixed heahtland. Main species are *Erica umbellata* and *Pterospartum tridentatum*.

Soils are umbric cambisols developed over paragneis parent material.

Experimental design

Nine experimental plots (11 x 7 m each) were set up at the beginning of the experiment with their longest dimension along the maximum slope. In each of these plots, 4 subplots (1 x 1 m each) were randomly installed. To study the effect of different fuel management tecniques, a randomized block design was used with three treatments: prescribed burning, shrub clipping + chopping and shrub clipping + extraction (manual).

Fuel inventories were carried out before and after treatments.

Rainfall simulations were conducted in June 2006, immediately after treatments application before any natural rainfall event had occurred. A rainfall simulator as described by Wilcox and others (1986) was used to apply rainfall to each runoff plot for 30 minutes. A rainfall rate of 67 mm h^{-1} was applied to each runoff plot. Although this rainfall intensity is high in this area, due to the small drop size produced by the rainfall simulator, the rainfall energy is more similar to that produced by lower rainfall intensities.

All runoff was routed through a collection tray at the bottom of each plot and collected in bottles on 1 minute intervals (from the start of rainfall) during the first 5 minutes and thereafter each tree minutes to the entire rainfall simulation. Metal borders inserted into the soil prevented surface inflow and outflow in the rainfall simulation plots.

Runoff samples were analysed for runoff volume. The sample was filtered through a Whatman filter, dried at 105ºC for 25 h weighed and converted in sediment yield.

Average infiltration rate (mm h^{-1}) for each time interval was calculated as the difference between rainfall and runoff by the time of the sample interval. Minimum infiltration rate was the lowest infiltration rate throughout the rainfall simulation. Total runoff (mm) was the cumulative runoff over the total sample time. Total sediment yield (kg ha^{-1}) was the sum of all the sediments collected over the rainfall run.

Before simulated rainfall was applied, percentage of canopy and ground cover were visually estimated. Organic layer (litter + duff) mass was measured by a destructive sampling using (0.30 x 0.30 m) quadrats. In the laboratory this material was dried at 105ºC until constant weight. Soil organic layer thickness and cover were measured in 16 points distributed in a grid inside each plot. Standard deviation of soil organic thickness was used as a measure of surface roughness.

Data analysis

Differences in mean infiltration rate and total runoff between treatments were analysed using one way ANOVA. A Kruskal-Wallis test was employed to analyze differences in total erosion . The degree of linear association of the variables most related to cumulative runoff and average infiltration rate and erosion was determined using a Pearson's correlation matrix (r). For erosion non parametric regression was employed. SPSS 13.0 (2004) was used for statistical analysis.

Results

The shrub biomass reduction was slightly lower in the burning treatment that also caused higher mineral soil exposition (*table 1*). The lowest percentage of bare soil was found after shrub chopping (*table 1*).

Table 1- *Mean fuel loading, litter thickness and percentage of bare soil before and after treatments. (standard error in brackets)*

	Prescribed Burn		**Shrub extraction**		**Shrub chopping**	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
Shrub stratum loading (kg m^{-2})	2.03 (0.14)	0.32 (0.06)	1.45 (0.76)	0	2.45 (0.18)	0
Soil organic layer thickness (cm)	2.3 (0.4)	1.0 (0.2)	2.3 (0.4)	1.8 (0.2)	3.7 (0.5)	3.2 (0.2)
Percentage of bare soil	0	27.3 (7.7)	0	18.7 (4.4)	0	4.7 (2.7)

Runoff and erosion

Shrub chopping had a significant influence on the time to initiate overland flow (*table 2*). However, no differences in cumulative runoff or mean infiltration rate were found between treatments. Soil erosion after treatments was very low in all the cases (*table 2*). However, significant differences between burned and unburned soils were found.

Table 2- *Average runoff, sediment and infiltration variables (in brackets, standard error).*

	Prescribed Burn	Shrub extraction	Shrub chopping
Time to runoff (s)	98 (9.0) a	92 (7.9) a	67 (7.5) b
Cumulative runoff (mm)	14.0 (1.6) a	10.0 (1.5) a	12.8 (1.9) a
Mean infiltration rate (mm h^{-1})	39.7 (3.2) a	47.4 (2.9) a	42.0 (3.8) a
Cumulative sediment (kg ha^{-1})	248.0 (46.0) a	32 (7.0) b	63.4 (16.0) b

Same letters in the same row, means did not statistically differ (P < 0.05)

Infiltration curves during the simulation runs were very similar in the three treatments (*fig. 1*).

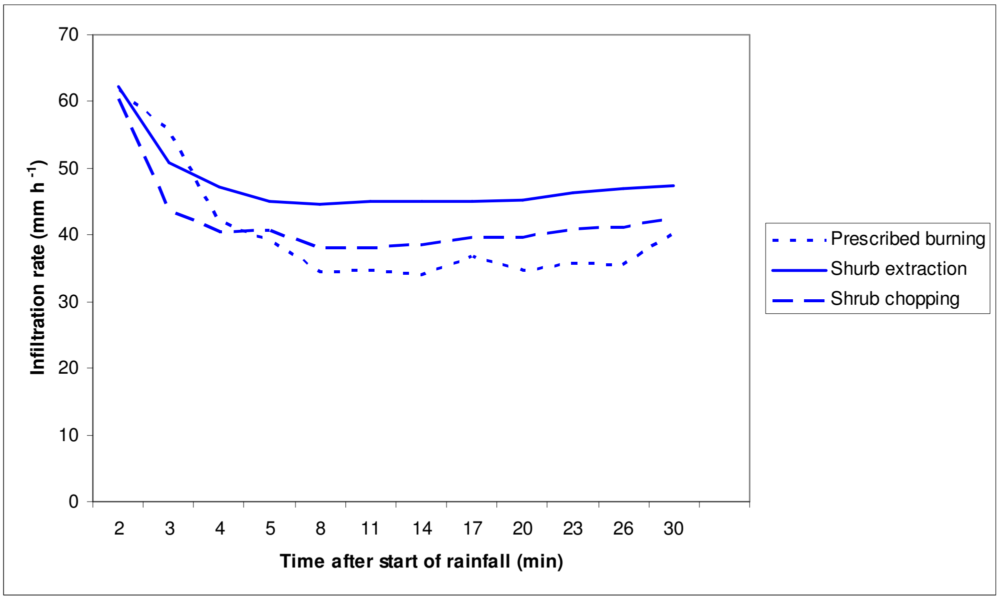

Figure 1- Average infiltration rate over time on treated plots.

Cumulative erosion for the whole data set was significant and negatively correlated with soil organic cover thickness for the whole data set (Tau = 0.322, n =36, p > 0.01). No significant correlation were found for cumulative runoff and mean infiltration rate.

When analysing each data set, only prescribed burn treatment yielded significant correlations (*table 3*). The variable that explained most of the studied changes was soil organic thickness .

Table 3- Pearson correlations coefficients (cumulative runoff and mean infiltration rate) and Tau (erosion data) between hydrologic and erosion variables and site characteristics for each set of data (n =12).

Dependent variable	Data set	Independent variable	Sign	r
Cumulative Runoff (mm)	Prescribed burning (n = 12)	Soil organic cover thickness	-	0.656*
Mean infiltration rate (mm h^{-1})	Prescribed burning (n = 12)	Soil organic cover thickness	+	0,680*
				Tau
Cumulative erosion	Prescribed burning (n = 12)	Soil organic cover thickness	-	0,455*

* P < 0.05

Discussion

Fuel reduction treatments caused low exposition after their application and the accumulated runoff and infiltration rate did nor differ between them. The significant higher time to runoff in shrub chopping treatment could have been originated from the chopped shrub mixtured with mineral soil.

In this study, soil organic cover thickness was the variable that showed most of the correlations with the dependent variables in the burned treatment. It is well established that soil organic cover remaining after fire provide surface roughness and adequate protection for the mineral soil from raindrop splash, overland flow detachment and rill development which can cause an increase in soil erosion and runoff (e.g. Emmerich and Cox, 1994; Robichaud and Waldrop, 1994; Robichaud *and others*, 1994; Robichaud, 2000; Pierson and others, 2002; De Luis and others, 2003). The importance of the remaining litter + duff depth agrees with the observations of Morales and others (2000) and Vega and others (2005) after prescribed burning.

No correlation of erosion with bare soil was found as the percentage of bare soil after treatments was very low.

Conclusions

A high-intensity rainstorm after fuel reduction treatments application did not cause detrimental effects on hydrological variables.

Soil organic cover statistically controlled soil erosion losses in burned soils.

Although small-plot data do not reflect actual runoff and sediment yield, they provides a means to compare treatments or soil conditions for some hydrologic characteristics.

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