Organic carbon exports by overland flow from recently burnt eucalypt stands, north-central Portugal

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Abstract

While it is well documented that wildfires can have major impacts on hydrological and erosion processes, the associated transport of organic matter has received considerably less research attention. The present study estimates post-fire carbon exports by overland flow from two eucalypt plantations during the first year following the wildfire at contrasting spatial scales, i.e. the micro-plot and slope scale. The temporal patterns of these carbon exports were also analyzed. Total organic carbon content in runoff samples was measured with a Shimazdu TOC-analyser. Total Organic Carbon (TOC) losses were greater at micro-plot scale than slope scale reflecting a stronger hydrological response at the smaller scale. The TOC losses at both sites and at both scales were largely determined by the Particulate Organic Carbon (POC), accounting for at least 83% of the exported TOC. In consequence, the contribution of DOC fraction in the TOC export it was lower. TOC losses varied markedly through time but did not reveal a clear decline with time-since-fire.

1 INTRODUCTION

It is now widely recognized that wildfires are a natural phenomenon in Mediterranean regions and that they have played a crucial role in the evolution of the ecosystems in the region (Naveh, 1990). In the past decades, however, fire regimes in Mediterranean Europe have markedly intensified due to human activities, including through land-use changes such widespread planting of highly flammable tree species (Shakesby, 2011). Wildfires now consume an average 500,000 ha per year in southern Europe (San Miguel & Cami, 2009), with Portugal standing out with some 100,000 ha (Pereira et al., 2005).

It is now also generally accepted that the indirect effects of wildfires can include strong and sometimes extreme increases in runoff generation and the associated losses of sediments (Shakesby, 2011). Such increases have also been observed for eucalypt and Maritime Pine plantations, the two principal fire-prone forest types in north-central Portugal (Ferreira et al., 2005; Prats et al., 2012; Shakesby et al., 1996). Arguably, fire-induced losses of soil per se pose a lesser risk of land degradation to Mediterranean ecosystem than losses of soil organic matter/carbon (SOM/C) and nutrients (Shakesby, 2011). Post-fire nutrient and SOM/C exports, however, have received comparatively little research attention, including in Portugal (Ferreira et al., 2005; Malvar et al., 2011; Thomas et al., 1999). For north-central Portugal, this research gap is being addressed by the FCT-funded project FIRECNUTS (PTDC/AGR-CFL/104559/2008), with this paper focussing on the organic carbon losses by overland flow for two of the project’s study sites.
2 METHODS

2.1 STUDY AREA AND SITES

This study was carried out in a forest area in the Sever do Vouga municipality, north-central Portugal, that was burnt by a wildfire during the summer of 2010. Within this “Ermida” burnt area of roughly 250 ha, two steep hill slopes (designated “Burnt 1” and “Burnt 2”) were selected for the present study. Both study sites were planted with eucalypt (Eucalyptus globulus Labill.) at the time of the wildfire, and displayed shallow soils derived from schists.

The main aim of this study was to provide initial estimates of possible carbon exports by overland flow from recently burnt eucalypt plantations. More specifically, this study wanted: (i) to compare, for two adjacent eucalypt plantations, the carbon export by the principal monthly runoff events during the first year following the wildfire; (ii) to compare the carbon losses at the scale of micro-plot versus hill slope (iii) to analyze the temporal patterns in carbon losses; (iv) to determine the contributions of the dissolved versus particulate fraction and, in the case of the dissolved fraction, of organic versus inorganic carbon.

Both hill slopes were instrumented with one unbounded plot of approximately 2m width, comprising 4 separate plot outlets that were all connected to one or more tanks of 60-70 L for collection of the overland flow (Figure 1). In addition, two pairs of micro-plots were installed at each site, at the length of the hill slope. The overland flow produced by the micro-plots was collected in tanks of 30 L. The installation of all plots took place during August 2010, before the occurrence of any significant rainfall. Rainfall was measured since the middle of August, using several automatic and collecting gauges in the burnt area.

2.2 FIELD DATA AND SAMPLE COLLECTION

From early September 2010, the overland flow accumulated in the tanks was measured at regular intervals and samples were taken for each individual (sub-)plot. This samples collection was done during two years but the present study, focused on the principal monthly runoff events during the first year after fire, from September 2010 to September 2011.

The samples were collected in 0.5 L polyethylene bottles that were pre rinsed with hydrochloric acid (pH < 2.0) and distilled and de-ionised water. Immediately after collection, the sample bottles were stored and transported to the laboratory in thermal boxes, and then stored at 4 ºC for up to 24 h before analysis.

2.3 LABORATORY ANALYSIS

A 50 mL sub-sample was filtered using a glass fibre filter (Milipore©HA membrane filter) with a 0.45 μm pore size, and both filter and filtrate were stored in a freezer before the actual laboratory analyses. The filter was analysed to determine the Particulate Organic Carbon (POC) load and the filtrate to determine the Dissolved Organic Carbon (DOC) content. These analyses were done using a Shimadzu TOC-5050A Analyser for filtrate and the SSM-5000 module for the filter. The Total Organic Carbon (TOC) export was computed using the sum of the organic carbon on the filter and the organic carbon in the filtrate.

3 RESULTS AND CONCLUSIONS

The selected monthly events from September 2010 to September 2011 corresponded to roughly 850 mm of rainfall. These events produced, on average, markedly greater inter-plot total organic carbon (TOC) losses at the Burnt 2 site than Burnt 1 site (33 vs. 14 g m⁻²) (Table 1). At the hill slope scale, TOC losses were considerably lower than at the micro-plot scale, and difference between little the two slopes, and in the opposite sense at the micro-plot scale (i.e. 4 and 6 g m⁻² for sites Burnt 2 and Burnt 1, respectively). The differences in TOC export between the two study sites at the hill slope scale could be explained by differences in overland flow (with runoff coefficients of 4 and 13 %) but the differences at the micro-plot scale could not (with runoff coefficients of 33 and 34 %). The TOC losses at both sites and at both scales were largely determined by the POC, accounting for at least 83% of the exported TOC. The predominance of the POC fraction was
Figure 2. Average values of particulate (POC), and dissolved (DOC) organic carbon losses and rainfall amount in the two eucalypt plantation during the first year after wildfire.

Table 1. Average values of runoff coefficient, total organic carbon losses (TOC), particulate (POC) and dissolved (DOC) organic carbon losses at the two recently burnt eucalypt plantations.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Burnt 1</th>
<th>Burnt 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope angle (°)</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Area (m²)</td>
<td>Micro-plot: 0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Slope: 112</td>
<td>192</td>
</tr>
<tr>
<td>Runoff coefficient (%)</td>
<td>Micro-plot: 34</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Slope: 13</td>
<td>4</td>
</tr>
<tr>
<td>TOC export (g/m²)</td>
<td>Micro-plot: 14</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Slope: 6</td>
<td>4</td>
</tr>
<tr>
<td>POC (g/m²)</td>
<td>Micro-plot: 12</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Slope: 2</td>
<td>4</td>
</tr>
<tr>
<td>DOC (g/m²)</td>
<td>Micro-plot: 2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Slope: 0.2</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Preliminary analysis of the temporal patterns (Figure 2) indicated that TOC losses varied strongly between the study months but without showing a clear decline with time-since-fire. Especially the micro-plots revealed clear peaks in the TOC exports. At the Burnt 1 site, the peak in average losses agreed well with the maximum rainfall amount whereas at Burnt 2 site it seemed to lag behind this rainfall maximum.

REFERENCES


