Response of runoff and erosion during extreme events to climate change in Mediterranean watersheds

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1. Introduction

Climate change is expected to increase temperatures and lower rainfall in Mediterranean regions, increasing the intensity of extreme rainfall events at the same time (e.g. Räisänen et al., 2004). These changes could impact the driving forces behind catchment response to storms in both positive and negative ways, since higher intensity could be counteracted by a decrease in hydrological connectivity caused by lower soil moisture. This work analyzed this problem for two watersheds with contrasting conditions, both located in Portugal: Odeleite, with a semi-arid climate and covered mostly by natural vegetation (particularly Mediterranean shrubs), and Alenquer, located in an agricultural region with a humid climate.

2. Methods

The objective of this work was to evaluate the response of catchment hydrological and erosion processes to likely changes in climate parameters, using a coupled hydrological and erosion simulation at both the seasonal and extreme event scales. Daily climate scenarios for the period from 2070 to 2100, for two CO_2 emission scenarios (A2 and B2), were generated using the PROMES regional climate model (Gallardo et al., 2001). The SWAT hydrological model (Neitsch et al., 2002) was run with these results to determine impacts on seasonal-scale soil moisture and vegetation cover. These results were used to parameterize the MEFIDIS storm-scale hydrological and erosion model (Nunes et al., 2005), aiming to verify the compounded impact of these changes on runoff and erosion during extreme events.

These changes were applied to 13 storms in Odeleite and 15 in Alenquer, with different rainfall and initial soil moisture conditions. Changes to event rainfall estimated by PROMES were applied directly to raingauge data, with a change of event intensity of half the ratio used to change event rainfall. Changes to soil moisture were estimated from SWAT results for changes to average baseflow conditions; a TOPMODEL-based approach was used to estimate the spatial distribution of soil water deficit from pre-storm baseflow (Beven, 2000). Changes to vegetation cover were estimated from SWAT results for changes to vegetation biomass production. The analysis focused on changes to watershed runoff, peak runoff rate and sediment yield, as well as within-watershed soil erosion patterns, runoff generation ratio and sediment delivery ratio.

3. Results and Discussion

The results from the PROMES regional climate model indicate a decrease in annual rainfall (20 to 30%) coupled with an increase in rainfall for extreme events during the latter part of the wet season (4 to 20%). Using these climate scenarios, SWAT results indicate that soil moisture is expected to decrease (35 to 70%) while vegetation cover is expected either to have no significant changes or, for natural shrublands, to increase up to 60%. Figure 1 shows these results for both watersheds, for all climate change scenarios and seasons. The Odeleite watershed shows a larger reduction of soil moisture and, in the A2 scenario, a larger increase of vegetation biomass, due mostly to CO_2 fertilization of shrubs. In Alenquer, the A2 scenario shows a significant increase of storm rainfall during the Winter/Spring season coupled with lower soil moisture decreases than in other scenarios, despite the larger decrease in annual rainfall predicted for this scenario (24.7 %, compared with 20.5 % for the B2 scenario).

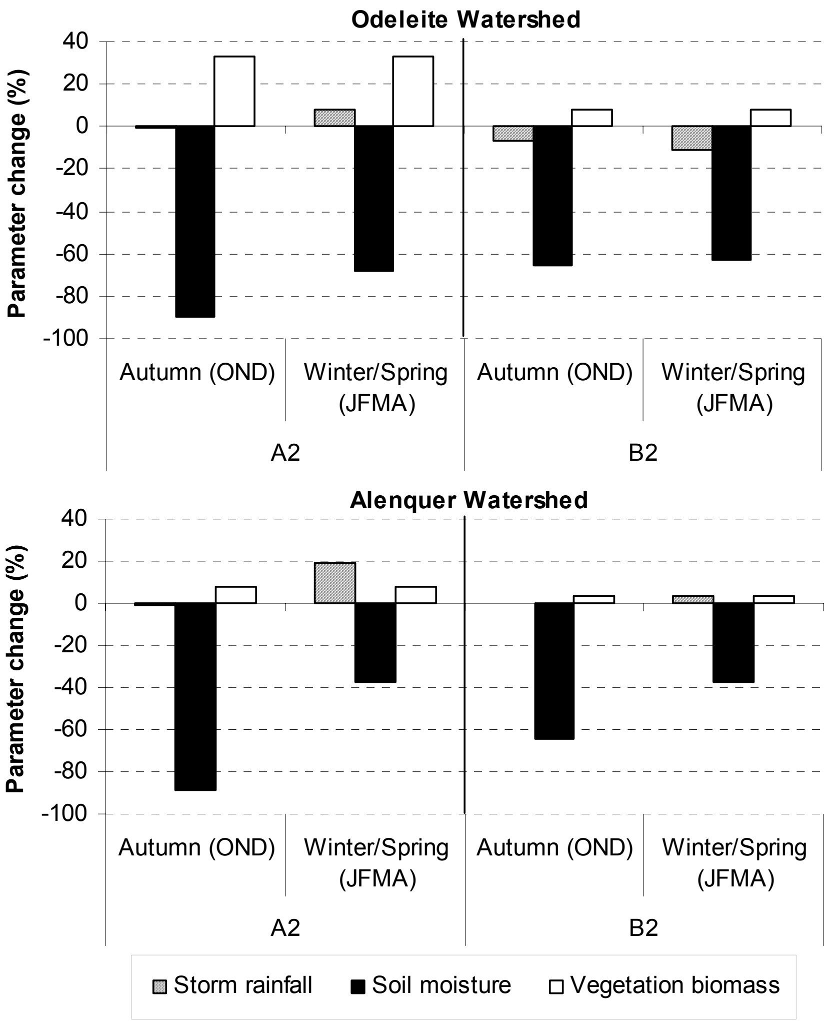

Figure 1 PROMES results for changes to storm rainfall, coupled with SWAT results for changes to soil moisture and vegetation biomass (averaged across species), for the Odeleite (top) and Alenquer (bottom) watersheds. Results are shown for climate change scenarios A2 and B2, with two seasons per scenario: Autumn (OND: October, November and December) and Winter/Spring (JMFA: January, February, March and April)

The main MEFIDIS results are shown in Figure 2 for storm runoff and in Figure 3 for within-watershed erosion. In Odeleite, results show a decrease in storm runoff and soil erosion in all scenarios, by 44 and 59 % respectively. Sediment yield shows a decrease of 86 %, showing a decrease of sediment connectivity coupled with a decrease in soil erosion. Furthermore, these impacts are smaller for the strongest storms which indicates that the most extreme floods could remain unchanged. Finally, these impacts occur mostly on Mediterranean shrublands; soil erosion in croplands within this watershed is predicted to decrease by a more modest 23 %.

In Alenquer, results show an increase in runoff and soil erosion during the Winter/Spring season for the A2 scenario, of 14 and 20 % respectively, despite a total rainfall decrease of 15 %. However, this is compensated by a large decrease in Autumn, leading to an overall reduction in both values. In both climate scenarios, runoff and erosion are expected to decrease by 17 and 28 % respectively. The storm runoff decrease is significantly smaller than the 39 % decrease in annual runoff predicted by the SWAT model.

Finally, it should be noted that changes to soil erosion in both watersheds were mostly in areas affected by significant erosion rates, which in MEFIDIS indicate regions with gully erosion. The decrease was mostly of the area affected by this process; remaining areas showed only small changes to erosion rates, and gully erosion is expected to remain the dominant erosion process.

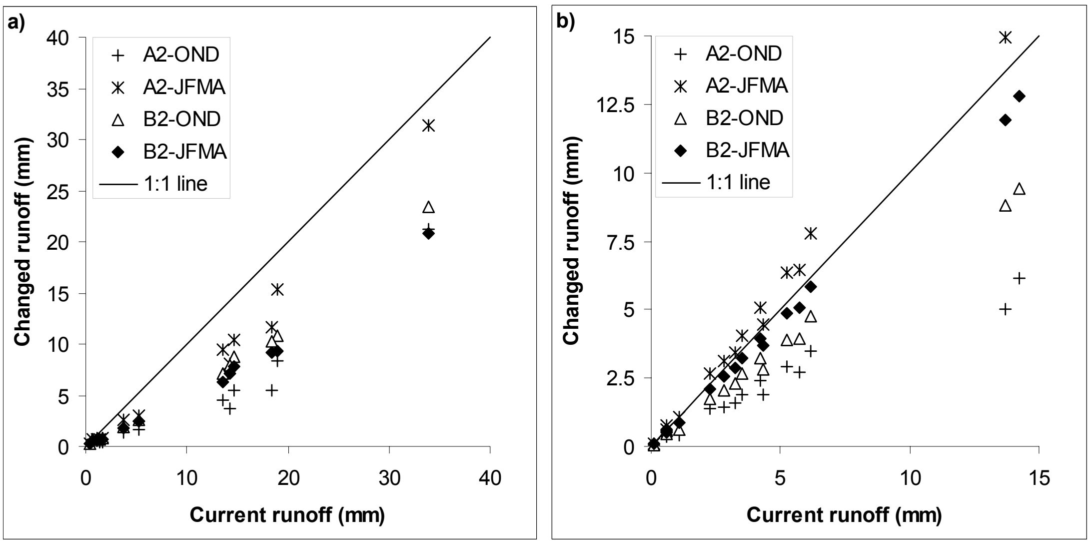

Figure 2 MEFIDIS results for changes to storm runoff, for Odeleite (a) and Alenquer (b). Results are shown for climate change scenarios A2 and B2, with two seasons per scenario: Autumn (OND: October, November and December) and Winter/Spring (JMFA: January, February, March and April)

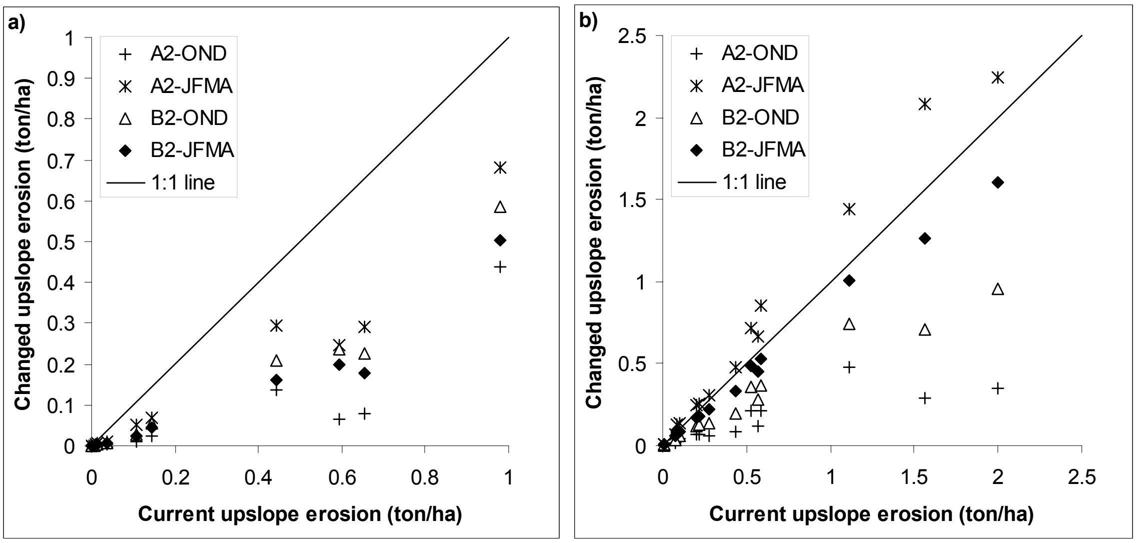

Figure 3 MEFIDIS results for changes to within-watershed erosion, for Odeleite (a) and Alenquer (b). Results are shown for climate change scenarios A2 and B2, with two seasons per scenario: Autumn (OND: October, November and December) and Winter/Spring (JMFA: January, February, March and April).

4. Conclusions

These results indicate that, for the climate change scenarios under analysis, the decrease in soil moisture due to climate change is likely to outweigh an increase in storm rainfall intensity. In consequence, storm runoff and soil erosion rates are expected to decrease, although with smaller changes than the reduction of annual rainfall would suggest. This is particularly noticeable in agricultural watersheds with a currently humid climate, where this response could actually increase despite the drier climate patterns, although it is difficult to estimate if increases in runoff and erosion during Winter and Spring can outweigh decreases during Autumn.

5. References

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