ADVANCES IN FOREST FIRE RESEARCH 2022

Edited by
DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO

Long-term erosion and the impact of wildfires: two different approaches

Joana Parente*[1]; João Pedro Nunes[1,2]; Jantiene Baartman[2]; Dante Föllmi[2]

[1] cE3c - Center for Ecology, Evolution and Environmental Changes & CHANGE - Global Change and Sustainability Institute, Sciences Faculty, University of Lisbon, Portugal {joaparente@gmail.com; joao.carvalhonunes@wur.nl}
[2]Soil Physics and Land Management Group, Wageningen University & Research, the Netherlands, {jantiene.baartman@wur.nl; dante.follmi@gmail.com}

**Corresponding author*

Keywords

Erosion; Sediment connectivity; post-fire; index of connectivity; modelling approach

Abstract

Rivers act as a network of channels that carry water, sediment, and energy downstream. On the heterogeneous area of the watershed, some areas might be responsive to disturbance (e.g., wildfires and droughts), while others may be resistant to the change. As a disturbance, fire is usually regarded as a key agent of soil erosion and land degradation. Fires are thought to be responsible for: (i) overland flow and reduction of the capacity of infiltration; (ii) increase of the availability of ash and debris and disruption of the soil nutrient cycle; and (iii) increase of connectivity across the watershed. The potential fire effects on soils and aquatic resources have created a strong demand for a post-fire sediment loss prediction tool. Taking this in mind, this study aims to assess post-fire soil erosion patterns at the decadal scale comparing different approaches. The methodology comprises (i) a process-based model that is able to investigate long-term and large-scale spatial landscape evolution, LAPSUS model; (ii) an index that represents a connectivity assessment based on local landscape information, the Borselli Index of Connectivity (IC); and (iii) and the sediment export that represents the sediment eroded that actually reaches the stream based on local landscape information, combining the IC with the Revised Universal Soil Loss Equation (RUSLE) model. Results include a comparison between the approaches used in the context of specific fire events between 1979 and 2020 for the Agueda watershed in central Portugal. The authors believe that assessing the spatial-temporal evolution of connectivity in the actual landscape with the appropriate tool is extremely important to estimate the probability that a given part of the landscape transfers its sediments downstream.

1. Introduction

Rivers act as a network of channels that carry water, sediment, and energy downstream (1). On the heterogeneous area of the watershed, some areas might be responsive to disturbance events (e.g., wildfires and droughts), while others may be resistant to the change (Khan et al., 2021).

Fire disturbance is usually regarded as a key agent of soil erosion and land degradation (Shakesby, 2011). Fire is pointed as responsible for: (i) overland flow and reduction of the capacity of infiltration (Basso et al., 2021; Fernández et al., 2010); (ii) increase of the availability of ash and debris and disruption of the soil nutrient cycle (Basso et al., 2021); and (iv) increase of connectivity across the watershed (van der Grift, 2021). The potential fire effects on soils and aquatic resources have created a strong demand for a post-fire sediment loss prediction tool (Fernández et al., 2010; Larsen & MacDonald, 2007; Vieira et al., 2014).

It is then important to have a working connectivity definition and usable indices and models to assess its spatial and temporal distribution. In this study, the authors work with the sediment connectivity definition recognized by the scientific community: the capacity of sediment to move through the watershed (Bracken & Croke, 2007; Crema & Cavalli, 2018; Hooke, 2003). To assess sediment connectivity spatial and temporal distribution the authors use three different approaches based on information available in a GIS environment: the Index of Connectivity (IC)(Borselli et al., 2008), the long-term landscape evolution model LAPSUS (Landscape Process Modelling at Multi-Dimensions and Scales) (Baartman et al., 2010; Temme et al., 2011), and the Sediment Export (SE) approach (Sharp et al., 2020).

This study seeks to answer the specific research questions: (i) "What aspect of connectivity do the different indexes and models measure?"; and (ii) "How these approaches are related?".

2. Data and Methods

This study focused on the Águeda watershed located in the central area of mainland Portugal. This watershed is a representative region where different agents contribute to landscape evolution/modification, and where sediment connectivity should consider the contribution of such agents to erosion and transport and their influence on the morphological settings that control sediment conveyance (Cavalli et al., 2013).

To assess sediment connectivity the authors used IC, LAPSUS, and SE for different soil burn severity scenarios for 1979-2020. These approaches need as inputs: (i) fire severity, (ii) land use information, (iii) USLE-C factor values; and (iv) annual soil parameters (P-factor, LS-factor, K-factor, and R-factor). To test independence and find interactions between the three approaches the authors used contingency tables, accuracy metrics and statistical measures of association.

3. Results and discussion

Results include the connectivity description and the comparison between the approaches in the context of specific fire events between 1979 and 2020. The three approaches take different times to be computed, due to the necessity of LAPSUS need to be calibrated. From the 3 approaches, LAPSUS needs more inputs and IC fewer inputs. The relation is better between LAPSUS and SE than between LAPSUS and IC. In addition, this relation between LAPSUS and the other approaches depends on the target year and/or fire characteristics.

4. Conclusion

This study presents 3 different approaches to assess sediment connectivity which lead to the identification of potential sources of ash and post-fire contaminants. The authors believe the results of this study are extremely important to estimate the probability that a given part of the landscape transfers its downstream.

5. Acknowledgements

This work was financed by the project FRISCO - managing Fire-induced RISks of water quality Contamination (PCIF/MPG/0044/2018) and supported by National Funds through FCT - Foundation for Science and Technology under the project UIDB/04033/2020, and funding attributed to the CE3C research center (UIDB/00329/2020).

6. References

Baartman, J. E. M., Schoorl, J. M., Veldkamp, T. A., & Ritsema, C. J. (2010). Erosion in a landscape evolution context : LISEM and LAPSUS. Library.Wur.Nl, 12(March), 3480. https://library.wur.nl/WebQuery/wurpubs/fulltext/14381

Basso, M., Mateus, M., Ramos, T. B., & Vieira, D. C. S. (2021). Potential Post-Fire Impacts on a Water Supply Reservoir: An Integrated Watershed-Reservoir Approach. Frontiers in Environmental Science, 9, 201. https://doi.org/10.3389/fenvs.2021.684703

Borselli, L., Cassi, P., & Torri, D. (2008). Prolegomena to sediment and flow connectivity in the landscape: A GIS and field numerical assessment. Catena, 75(3), 268–277. https://doi.org/10.1016/j.catena.2008.07.006

Bracken, L. J., & Croke, J. (2007). The concept of hydrological connectivity and its contribution to understanding runoff-dominated geomorphic systems. Hydrological Processes, 21(13), 1749–1763. https://doi.org/10.1002/HYP.6313

Cavalli, M., Trevisani, S., Comiti, F., & Marchi, L. (2013). Geomorphometric assessment of spatial sediment connectivity in small Alpine catchments. Geomorphology, 188, 31–41. https://doi.org/10.1016/j.geomorph.2012.05.007

Crema, S., & Cavalli, M. (2018). SedInConnect: a stand-alone, free and open source tool for the assessment of sediment connectivity. Computers and Geosciences, 111, 39–45. https://doi.org/10.1016/j.cageo.2017.10.009

Fernández, C., Vega, J. A., & Vieira, D. C. S. (2010). Assessing soil erosion after fire and rehabilitation treatments in NW Spain: Performance of rusle and revised Morgan-Morgan-Finney models. Land Degradation and Development, 21(1), 58–67. https://doi.org/10.1002/ldr.965

Hooke, J. (2003). Coarse sediment connectivity in river channel systems: A conceptual framework and methodology. Geomorphology, 56(1–2), 79–94. https://doi.org/10.1016/S0169-555X(03)00047-3

Khan, S., Fryirs, K., & Bizzi, S. (2021). Modelling sediment (dis)connectivity across a river network to understand locational-transmission-filter sensitivity for identifying hotspots of potential geomorphic adjustment. Earth Surface Processes and Landforms. https://doi.org/10.1002/ESP.5213/FORMAT/PDF

Larsen, I. J., & MacDonald, L. H. (2007). Predicting postfire sediment yields at the hillslope scale: Testing RUSLE and Disturbed WEPP. Water Resources Research, 43(11). https://doi.org/10.1029/2006WR005560/FORMAT/PDF

Shakesby, R. A. (2011). Post-wildfire soil erosion in the Mediterranean: Review and future research directions. Earth-Science Reviews, 105(3–4), 71–100. https://doi.org/10.1016/J.EARSCIREV.2011.01.001

Sharp, R., Douglass, J., Wolny, S., Arkema, K., Bernhardt, J., Bierbower, W., Chaumont, N., Denu, D., Fisher, D., Glowinski, K., Griffin, R., Guannel, G., Guerry, A., Johnson, J., Hamel, P., Kennedy, C., Kim, C. K., Lacayo, M., Lonsdorf, E., … Wyatt, K. (2020). SDR: Sediment Delivery Ratio — InVEST documentation. In R. Sharp, J. Douglass, & S. Wolny (Eds.), InVEST 3.10.2.post63+ug.ga451015 User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund. https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/sdr.html?highlight=rainfall%20erosivity%20index

Temme, A. J. A. M., Claessens, L., Veldkamp, A., & Schoorl, J. M. (2011). Evaluating choices in multi-process landscape evolution models. Geomorphology, 125(2), 271–281. https://doi.org/10.1016/j.geomorph.2010.10.007

van der Grift, S. (2021). The effect of wildfires on sediment connectivity using the AIC method - Long term analysis for the Águeda catchment in Portugal from 1979 until 2019. Wageningen University.

Vieira, D. C. S., Prats, S. A., Nunes, J. P., Shakesby, R. A., Coelho, C. O. A., & Keizer, J. J. (2014). Modelling runoff and erosion, and their mitigation, in burned Portuguese forest using the revised Morgan-Morgan-Finney model. Forest Ecology and Management, 314, 150–165. https://doi.org/10.1016/j.foreco.2013.12.006