ADVANCES IN FOREST FIRE RESEARCH 2022

Edited by
DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO

FRISCO: Managing fire-induced risks of water quality contamination

Joana Parente*[1]; João Pedro Nunes[1,2]; Luís Dias[1]; Akli Benali[3]; Marta Marques[4]; Oscar González-Pelayo[5]; Ana Sá[3]; Dina Jahanianfard[3]; Niels Nitzsche[1]; Beatriz Faria[1]; Bruno Aparício[1,3]; Tomás Calheiros[1]; Jinfeng Wu[1]; Jantiene Baartman[2]; Dante Föllmi[2]; Stefan van der Grift[2]; Carlos Brito[4]; Amandine Valérie Pastor[1,6,7]

[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, lfdias@fc.ul.pt, Niels.Nitzsche@gmx.de, faribia@gmail.com, amandine.pastor22@gmail.com, bruno.a.aparicio@gmail.com, tlmenezes@fc.ul.pt, jinfengwu2020@163.com}

[2]Soil Physics and Land Management Group, Wageningen University & Research, the Netherlands, {jantiene.baartman@wur.nl, dante.follmi@gmail.com}

[3]Forest Research Centre (CEF), Instituto Superior de Agronomia, University of Lisbon, Portugal, {aklibenali@gmail.com, anasa30@gmail.com, dinaj@ua.pt}

[4]AdP Valor. Portugal, {m.carvalho@ADP.PT, carlos.brito@ADP.PT}

[5]Centre of Environmental and Marine Studies (CESAM), University of Aveiro, Portugal, {oscargonzalezpelayo@ua.pt}

[6]ITAP, Univ. Montpellier, INRAE, Montpellier SupAgro, Montpellier, France

[7]ELSA, Research Group for Environmental Life Cycle Sustainability Assessment, Montpellier France

**Corresponding author*

Keywords

Fire assessment and modelling; burnt area hydrology; hydrological ecosystem services; water resources management

Abstract

Fires can contaminate streams with fine sediments, nutrients, and ashes, threatening aquatic ecosystems and water supplies. Recent research on sediment and contaminant mobilization processes in burnt areas exists but linking mobilization with water contamination processes at larger scales remains challenging. In the FRISCO project, we argue that recent advances in understanding fire behavior and post-fire landscapes can overcome the major challenges in assessing and managing post-fire contamination risks. Links between fire characteristics and hydrologic impacts can be assessed by combining remote sensing and modeling tools with studies on fire severity and impacts on vegetation and soils. The impacts of fires on contaminant transport pathways can be assessed by combining landscape connectivity and hydrological modeling of burnt areas with field research on contaminant mobilization and transport. Overall, FRISCO researchers want to investigate the vulnerability of Mediterranean streams and water resources to contamination by fires. Our main results include: (i) map of post-fire sediment and ash transport pathways using satellite imagery; and (ii) statistical analysis of relation between fire characteristics (e.g., burnt area and fire severity) and water contaminants. We hope that the results help stakeholders in the development of the best practices for post-fire contamination management.

1. Introduction

Land abandonment in the Mediterranean has led to the combination of fuel build-up with widespread afforestation and an increase in the frequency and severity of wildfires (Moreira et al., 2020). Post-fire processes can contaminate streams with fine sediments, nutrients, and ashes (Verkaik et al., 2013), threatening aquatic ecosystems (Martin, 2016) and water supplies (Shakesby et al., 2016). Recent research focuses on sediment and contaminant mobilization processes in burnt areas (Nunes, Doerr, et al., 2018), but difficulties in linking mobilization with water contamination processes at larger scales persist (Santín et al., 2016).

We argue that recent developments in understanding fire behavior and post-fire landscapes can overcome most of those difficulties (Santín et al., 2016), such as: (i) the relationship between fire spread descriptors and hydrological impacts (Nunes, Doerr, et al., 2018; Sá et al., 2017), using the combination of remote sensing techniques and modeling (Benali et al., 2017; Chafer et al., 2016; Sá et al., 2018) tools with studies on burn severity and impacts on vegetation and soils (Cardil et al., 2019; Keesstra et al., 2018; Moody et al., 2016) to estimate the hydrological impacts of fires at large scales; and (ii) the impacts of fires on contaminant transport pathways (Martínez-Murillo & López-Vicente, 2018) using the latest methodologies of landscape connectivity (Martínez-Murillo & López-Vicente, 2018; Nunes, Naranjo Quintanilla, et al., 2018) and hydrological modeling of burnt areas (Campos et al., 2016) combined with field research on contaminant mobilization and transport (Hawtree et al., 2014).

The FRISCO project takes advantage of these advances to answer the question: How vulnerable are Mediterranean streams and water resources to contamination by fires? This study aims to present the current developments of the project on developing the information and tools needed to address this question.

2. Data and Methods

The FRISCO project focuses on Portugal as representative of the Mediterranean region. Portugal has an extensive forest cover and has experienced frequent and recurrent forest fires since the 1970s under two distinct fire regimes (Santín et al., 2016). It also has a large and open-access historical water quality database (SNIRH; http://snirh.pt).

This project has 72 main study areas that: (i) represent key water supply sources, e.g., direct water uptake from streams, low-capacity reservoirs, and large volume reservoirs; (ii) represent different fire regimes; and (iii) have available water quality data from the SNIRH network.Currently, we are working on 3 of 5 main tasks of FRISCO:

Task 1 - Characterization of fire impacts on vegetation and soils**:** with the main objective of combining satellite imagery and field data to characterize the fire impacts on vegetation and soils in mainland Portugal, in the last 20 years (2001 to 2020);

Task 2 – Characterization of fire impacts on contaminant mobilization and transport to streams: with the main objective of combining the information produced in task 1 with the new developments in connectivity theory and modelling, to characterize the contaminant mobilization and transport to streams for key water supply sources;

Task 3 - Identification of post-fire contamination episodes in key water supply sources and their main drivers: used historical water quality data and statistical analysis to identify post-fire contamination episodes in the key water supply sources in the last 20 years and assess their main drivers in coordination with water managers.

3. Results and discussion

The results of the 1st stage of FRISCO project show the new state of the art in the study of post-fire water contamination and in the establishment of the relationship between port-fire processes and post-fire hydrology. In particular, (i) the modelling of post-fire sediment and ash transport pathways using satellite imagery datasets; and (ii) the improvement of knowledge on the relations between fire, vegetation, soils, and water, which was done through statistical analysis of relation between fire characteristics (e.g., burnt area and fire severity) and water contaminants.

4. Conclusion

The FRISCO project had advanced the state of the art in the development of new knowledge on the relations between fire, vegetation, soils, and water, overcoming the main limitation for further progress (Santín et al., 2016); help understand and assess the impacts of fire on the provision of hydrological services by forests (Campos et al., 2016); and take fire into account in the assessment of the impacts of climate and land-use changes on water resources, addressing a major uncertainty in adaptation to climate change planning (Santín et al., 2016). As future work, we hope to (i) model a contamination risk index, which will arise to an operational tool that will allow qualitative risk for each water body; and (ii) a combined fire and contamination model that will help to get an operational risk mitigation manual for water managers.

5. Acknowledgements

This work was financed by the project FRISCO - managing Fire-induced RISks of water quality Contamination (PCIF/MPG/0044/2018). This work was also 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

Benali, A., Sá, A., Ervilha, A., & Trigo, R. (2017). Fire spread predictions: Sweeping uncertainty under the rug. Science of The Total Environment. https://www.sciencedirect.com/science/article/pii/S0048969717306186?casa_token=Z01yXNxYLnwAAAAA:lX7xh_35dori-Ro8hxF5HpVjs6E2e4Gl4cWJ9qmFNyL4q9fU5XO5pOzOkBt-sMAxkeC2tX4j

Campos, I., Abrantes, N., Keizer, J., & Vale, C. (2016). Major and trace elements in soils and ashes of eucalypt and pine forest plantations in Portugal following a wildfire. Science of The Total Environment. https://www.sciencedirect.com/science/article/pii/S0048969716301863?casa_token=1E3IhltW3FYAAAAA:n90fI1VSYUiv2fP9T2HzgKTmfLAvM3m7FX_csqSpQoaRlthLOG588cAYkur9FGf4qYjpuhZQ

Cardil, A., Mola-Yudego, B., Blázquez-Casado, Á., & González-Olabarria, J. R. (2019). Fire and burn severity assessment: Calibration of Relative Differenced Normalized Burn Ratio (RdNBR) with field data. Journal of Environmental Management, 235, 342–349. https://doi.org/10.1016/j.jenvman.2019.01.077

Chafer, C. J., Santín, C., & Doerr, S. H. (2016). Modelling and quantifying the spatial distribution of post-wildfire ash loads. International Journal of Wildland Fire, 25(2), 249. https://doi.org/10.1071/WF15074

Hawtree, D., Nunes, J. P., Keizer, J. J., Jacinto, R., Santos, J., Rial-Rivas, M. E., Boulet, A.-K., Tavares-Wahren, F., & Feger, K.-H. (2014). Time series analysis of the long-term hydrologic impacts of afforestation in the Águeda watershed of north-central Portugal. Hydrology and Earth System Sciences, 11, 12223–12256. https://doi.org/10.5194/hessd-11-12223-2014

Keesstra, S., Nunes, J. P., Saco, P., Parsons, T., Poeppl, R., Masselink, R., & Cerdà, A. (2018). The way forward: Can connectivity be useful to design better measuring and modelling schemes for water and sediment dynamics? In Science of the Total Environment (Vol. 644, pp. 1557–1572). https://doi.org/10.1016/j.scitotenv.2018.06.342

Martin, D. A. (2016). At the nexus of fire, water and society. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1696). https://doi.org/10.1098/RSTB.2015.0172

Martínez-Murillo, J. F., & López-Vicente, M. (2018). Effect of Salvage Logging and Check Dams on Simulated Hydrological Connectivity in a Burned Area. Land Degradation and Development, 29(3), 701–712. https://doi.org/10.1002/LDR.2735

Moody, J. A., Ebel, B. A., Nyman, P., Martin, D. A., Stoof, C., & McKinley, R. (2016). Relations between soil hydraulic properties and burn severity. International Journal of Wildland Fire, 25(3), 279. https://doi.org/10.1071/WF14062

Moreira, F., Ascoli, D., Safford, H., Adams, M. A., Moreno, J. M., Pereira, J. M. C., Catry, F. X., Armesto, J., Bond, W., González, M. E., Curt, T., Koutsias, N., McCaw, L., Price, O., Pausas, J. G., Rigolot, E., Stephens, S., Tavsanoglu, C., Vallejo, V. R., … Fernandes, P. M. (2020). Wildfire management in Mediterranean-type regions: paradigm change needed. Environmental Research Letters, 15(1), 011001. https://doi.org/10.1088/1748-9326/ab541e

Nunes, J. P., Doerr, S. H., Sheridan, G., Neris, J., Santín, C., Emelko, M. B., Silins, U., Robichaud, P. R., Elliot, W. J., & Keizer, J. (2018). Assessing water contamination risk from vegetation fires: Challenges, opportunities and a framework for progress. Hydrological Processes, 32(5), 687–694. https://doi.org/10.1002/hyp.11434

Nunes, J. P., Naranjo Quintanilla, P., Santos, J. M., Serpa, D., Carvalho-Santos, C., Rocha, J., Keizer, J. J., & Keesstra, S. D. (2018). Afforestation, Subsequent Forest Fires and Provision of Hydrological Services: A Model-Based Analysis for a Mediterranean Mountainous Catchment. Land Degradation & Development, 29(3), 776–788. https://doi.org/10.1002/ldr.2776

Sá, A., Benali, A., Fernandes, P., & Pinto, R. (2017). Evaluating fire growth simulations using satellite active fire data. Remote Sensing of Environment, 190, 302–317. https://doi.org/10.1016/j.rse.2016.12.023

Sá, A., Turkman, M., & Pereira, J. (2018). Exploring fire incidence in Portugal using generalized additive models for location, scale and shape (GAMLSS). Modeling Earth Systems and Environment, 4(1), 199–220. https://doi.org/10.1007/s40808-017-0409-6

Santín, C., Doerr, S. H., Kane, E. S., Masiello, C. A., Ohlson, M., de la Rosa, J. M., Preston, C. M., & Dittmar, T. (2016). Towards a global assessment of pyrogenic carbon from vegetation fires. Global Change Biology, 22(1), 76–91. https://doi.org/10.1111/gcb.12985

Shakesby, R. A., Moody, J. A., Martin, D. A., & Robichaud, P. R. (2016). Synthesising empirical results to improve predictions of post-wildfire runoff and erosion response. In International Journal of Wildland Fire (Vol. 25, Issue 3, pp. 257–261). https://doi.org/10.1071/WF16021

Verkaik, I., Rieradevall, M., Cooper, S. D., Melack, J. M., Dudley, T. L., & Prat, N. (2013). Fire as a disturbance in mediterranean climate streams. Hydrobiologia, 719(1), 353–382. https://doi.org/10.1007/s10750-013-1463-3