What is wrong with post-fire soil erosion modelling?

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Objectives :

This work meta-analyzed the scientific advances in the last twenty years in post-fire soil erosion modelling, conducting a critical review of the modelling approaches used and providing guidelines for future studies.
More specifically, we analyzed whether modelling addressed: i) fire-induced changes in soil structure, water infiltration, and cover; ii) burn severity; and iii) the application of post-fire soil erosion mitigation treatments.

Methodology:

A search was conducted in the Scopus database for articles published until 2019 (Figure 1), aimed at finding publications that addressed the specific objectives.
This search retrieved 664 works that were screened and excluded based on the criteria defined in Lopes et al. (2021), resulting in 41 publications in which 52 cases were identified according to the model used**.**

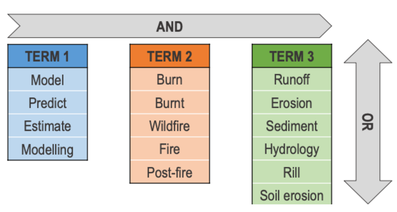

Figure 1. Combination of search terms used in the SCOPUS database.

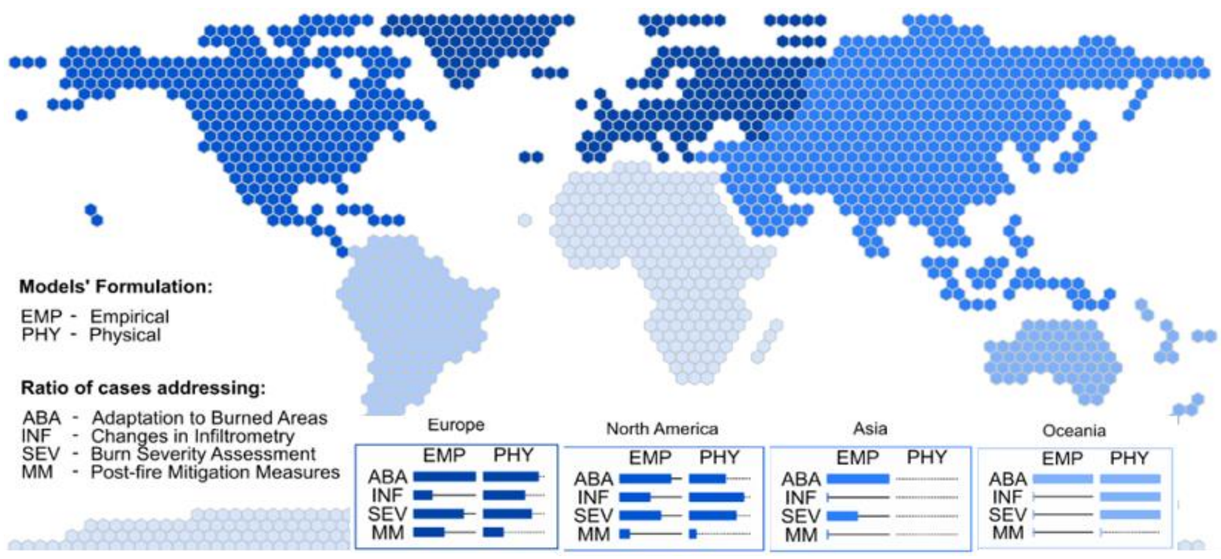

Figure 2. Ratio of cases addressing the key-factors in post-fire hydrological response for each model type.

Results:

- Modelling studies were performed in only four continents (Figure 2), predominantly in Europe (25) and United States (23). Empirical models were mostly used in Europe (64%), whilst in the United States there was a preference towards the physically-based ones (63%);
- In 73% of the cases, models were adapted to post-fire conditions using existing equations or methods, but only 21% modified inputs or model components with new formulations or processes for burned areas (Table 1);
- Fire-induced changes in soil structure and ground cover were mostly simulated by adjusting soil erodibility and cover factors, whereas soil hydraulic parameters were modified to account for changes in infiltration;
- In 60% of the cases, efficiency metrics were used to assess model performance (Table 1), but only in 17% the modelled data were validated with independent datasets;
- The most used efficiency indices were the coefficient of determination (R^2), Nash-Sutcliffe efficiency (NSE) and the root mean square error (RMSE). R^2 values for empirical and physical based models showed similar dispersion, NSE indicate that physical models overperformed the empirical ones and RMSE had a similar behavior than NSE (Lopes et al., 2021);
- in 13% of the cases the uncertainty/sensitivity of the predictions was analyzed (Table 1).

Table 1. Percentage of the total number of the study cases that addressed the research questions of the meta-analysis.

	Research questions	Cases (%)
Predictions	Erosion	100
	Runoff/Discharge	46
Model calibration	Unburned	50
	Model adaptation to burned areas	73
	Is infiltration addressed?	58
	Is burn severity addressed?	75
	Improvement of model components	21
	Post-fire rehabilitation measures	27
Efficiency assessment	Use of efficiency indices	60
	Validation	17
	Uncertainty/sensitivity analysis	13
Structural	Empirical	48
	Physical	52
	Process-oriented	29
	Spatially distributed	42

Conclusions:

From the obtained results, we can conclude that for improving post-fire soil erosion modelling, and the communication of scientific outputs, future modelling works should:

- further address changes in soil and infiltration;
- include model efficiency indices and separate into calibration and validation phases;
- test a multidisciplinary model combination to tackle post-fire management in an integrated way;
- consider developing and testing models that allow the adjusting post-fire infiltration changes, calibrating the cover factor to the degree of burn severity and include a wide array of post-fire mitigation measures;
- conduct uncertainty analyses and identify ways to further improve the accuracy of predictions.

References:

Lopes, A.R.; Girona-García, A.; Corticeiro, S., Martins, R.; Keizer, J.J.; Vieira, D.C., 2021. What is wrong with post-fire soil erosion modelling? A meta-analysis on current approaches, research gaps, and future directions. Earth Surface Processes and Landforms 46: 205-2019. DOI: 10.1002/esp.5020.

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