

From vegetation monitoring to seasonal wildfire danger forecasting in Portugal

Filippe L.M. Santos⁽¹⁾, Flavio T. Couto^(1,2), Maria J. Monteiro⁽³⁾, Nuno Almeida Ribeiro^(1,4), Rui Salgado^(1,2)

- (1) Universidade de Évora, Center for sci-tech Research in EArth sysTem and Energy (CREATE), Rua Romão Ramalho 59, 7000-671, Évora, Portugal
- (2) Universidade de Évora, Escola de Ciências e Tecnologia, Departamento de Física, Rua Romão Ramalho, 59, 7000-671, Évora, Portugal
- (3) Instituto Português do Mar e da Atmosfera, Rua C do Aeroporto, 1749-077, Lisboa, Portugal
- (4) Universidade de Évora, Escola de Ciências e Tecnologia, Departamento de Fitotecnia, Pólo da Mitra, Ap. 94, 7006-554, Évora, Portugal

Wildfire danger in Mediterranean ecosystems is strongly influenced by seasonal changes in vegetation moisture and fuel conditions. However, monitoring and predicting these dynamics remains challenging due to vegetation heterogeneity, limited field observations, and complex land-atmosphere interactions. This research develops a framework for monitoring and forecasting live fuel moisture content (LFMC) in Portugal, integrating remote sensing, machine learning, and land surface modeling. First, field spectroradiometry, unmanned aerial vehicle imagery, and Sentinel-2 observations were combined to investigate seasonal LFMC variability in Mediterranean shrublands. This analysis revealed minimum moisture values during summer and highlighted the importance of short-wave infrared information. Subsequently, field measurements and Sentinel-2 data were integrated using machine learning to estimate above-ground biomass and LFMC, characterizing vegetation fuel conditions across southern Portugal. Building on these observations, a hybrid framework combined remote-sensing-derived LFMC estimates with simulations from the SURFEX land surface model driven by AROME numerical weather predictions. A Random Forest approach reproduced seasonal LFMC patterns across mainland Portugal, including spatial contrasts associated with vegetation characteristics and land cover. Finally, the framework was extended to seasonal prediction by using ensemble forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF) SEAS5 system to force SURFEX. This approach enabled probabilistic forecasts of vegetation moisture up to three months in advance, identifying areas potentially exposed to critically low LFMC. Despite uncertainties related to field sampling, scale differences, and forecast biases, the results demonstrate its potential for seasonal wildfire early-warning applications. Overall, this research establishes a pathway from vegetation observation to seasonal prediction, improving the representation of live fuel conditions and complementing meteorological fire danger indicators. The proposed framework supports anticipatory wildfire management, fuel monitoring, and decision-making in Mediterranean environments.

Acknowledgements

This work was supported by FCT - Fundação para a Ciência e Tecnologia, I.P., by project reference 2022.11960.BD and DOI identifier <https://doi.org/10.54499/2022.11960.BD>, by PyroC.pt project reference PCIF/MPG/0175/2019 and by Center for sci-tech Research in EArth sysTem and Energy - CREATE project reference UIDB/06107/2025. This research was also funded by the European Union through the European Regional Development Fund (FEDER) in the framework of the Interreg VI-A España-Portugal (POCTEP) 2021-2027, FIREPOCTEP+ (0139_FIREPOCTEP_MAS_6_E).