Cuadernos de Investigación Geográfica *Geographical Research Letters*	2025	Nº 51 (2)	pp. 5-7	EISSN 1697-9540

http://doi.org/10.18172/cig.7124

FOREST FIRES: RISK, CONSEQUENCES, AND TECHNOLOGICAL ADVANCES IN THEIR ANALYSIS AND MANAGEMENT

FERNANDO PÉREZ-CABELLO[1], RAQUEL MONTORIO LLOVERIA[1], MARCOS FRANCOS[2]

Guest Editors

[1] *Departamento de Geografía y Ordenación del Territorio, Instituto Universitario de Ciencias Ambientales (IUCA), Universidad de Zaragoza, Zaragoza, Spain.*

[2] *Department of Geography, Faculty of Geography and History, University of Salamanca, Cervantes s/n, 37002 Salamanca, Spain.*

In recent decades, wildfire regimes worldwide have undergone significant alterations due to the interaction of multiple factors, including the increasing intensity and frequency of heatwaves and droughts, and the effects of changing land-use and productive practices on forest ecosystems. Under these conditions, the negative impacts of wildfires, most notably the emission of large quantities of greenhouse gases, the degradation of soil properties, biodiversity loss, and the disruption of hydrological and carbon cycles, have been amplified. Furthermore, to these environmental impacts, we must add the destruction of infrastructure and material assets and, most importantly, the threat to human lives.

Wildfires, therefore, are among the most pressing environmental challenges of our time, reshaping ecosystems, economies, and societies amid accelerating global change. The complexity of their causes and consequences demands an interdisciplinary approach—one that combines prevention and management strategies with ecological understanding, technological innovation, and social engagement. To quantify wildfire risk and assess fire impacts from a multidisciplinary perspective, it is essential to develop and apply modelling and monitoring tools across multiple spatial and temporal scales, combining advanced geospatial technologies with field-based approaches. By doing this, researchers and managers can identify risk patterns, assess damages, and design context-specific recovery strategies, thereby optimising decision-making and long-term planning.

This Special Issue adopts an integrative perspective on the wildfire phenomenon, encompassing prevention and management strategies, the assessment of ecological and environmental impacts, post-fire recovery and restoration processes, and the application of advanced technologies and models for fire analysis. It also includes studies exploring the links between global change and fire dynamics, as well as contributions that emphasise education, innovation, and social engagement as essential pillars for achieving more sustainable and resilient forest management.

Most of the articles included in this Special Issue stem from the XI International Fuegored Congress (*Red Temática Internacional: Efectos del Fuego en Ecosistemas Forestales*), which brought together experts and professionals to share the latest research and advances in fire science and management (Salamanca, October 2024; [https://fuegored2024.usal.es/]). One of the Fuegored network's ([https://fuegored.weebly.com/]) objectives is to promote the dissemination of scientific research findings and provide technicians and managers with information that will enable them to improve forest management. The aim is to review the scientific knowledge developed to date and discuss and agree on the future direction of scientific research into the effects of fire, not only on soils but on all components of an ecosystem. Today, the network includes over 500 members: students and researchers from universities and research centres around the world, along with managers and technicians from public and private institutions, foundations, and NGOs. Together, they bring decades of scientific and technical experience to the table.

Regarding the papers focused on advancing the spatial and methodological frameworks for wildfire prevention and risk management, Coutinho and Marchioro (2025) analyse fire risk zoning in southeastern Brazil through a multi-criteria Analytic Hierarchy Process, revealing how both natural and socioeconomic factors contribute to varying levels of risk across the landscape. The results confirm that anthropogenic pressures and prolonged rainfall deficits are critical determinants that significantly increase the incidence of fires, posing a considerable threat to both human populations and ecological integrity. This study reinforces the need to adopt holistic perspectives in fire risk management, emphasising the importance of integrating the dynamic human and climatic variables that govern fire initiation and spread. The methodological framework established in this case study is expected to serve as a valuable precedent contributing to the refinement of predictive models and strategic planning in future forest fire research.

The contribution by Crespo *et al.* (2025) offers a regional perspective from Chile, where machine learning models identify the dominant ignition drivers across contrasting ecological zones, highlighting the critical role of anthropogenic factors. Predictive accuracy (AUC) was higher in southern regions, likely due to simpler landscapes and lower ignition densities. In contrast, predictive power declined in the highly complex central zone, highlighting the inherent challenges of modelling areas with intricate interactions between human and environmental pressures. Complementing these insights, Suárez-Seoane *et al.* (2025) propose an innovative multi-ring analytical framework to assess fire severity in the wildland–urban interface (WUI) of Ibero-Atlantic landscapes, emphasising the role of vegetation characteristics and spatial gradients in explaining severity differences. Collectively, these studies enrich our understanding of fire risk dynamics and provide practical tools for anticipating and mitigating wildfire hazards across diverse biogeographical and socio-environmental contexts.

The paper by Francos *et al.* (2025) explores the ecological consequences of fire on soils, providing long-term evidence of how prescribed burning and pre-fire land-use conditions influence post-fire soil chemistry recovery and resilience. Their 13-year monitoring in the Mediterranean Basin demonstrates that, notwithstanding short- and medium-term differences, prescribed fires do not cause lasting soil degradation, supporting their use as sustainable management tools. Despite this, the authors consider it essential to take into account the land use prior to burning, since, depending on the type of use and intensity, i) prescribed burning can affect some of the soil's chemical properties, even in the long term, and ii) the recovery of the ecosystem may be slower, leaving these areas more vulnerable to the impact of potential forest fires. Therefore, the use of the land prior to the fire is a fundamental factor in determining the recovery of the ecosystem.

Several contributions focus on post-fire recovery processes. Martín-Ortiz *et al.* (2025) use remote sensing data and machine learning methods to analyse how fire alters vegetation composition and Leaf Area Index (LAI) distribution in Mediterranean ecosystems, finding that pre-existing vegetation types strongly determine regeneration trajectories and ecosystem functionality. In turn, Nunes *et al.* (2025) document the severe impacts of large-scale fires on the wetlands of Brazil's Pantanal, using unmanned aerial vehicle (UAV) imagery to reveal both spectral and ecological degradation of macrohabitats and their partial recovery over subsequent years. Together, these studies highlight the importance of assessing ecosystem resilience to inform effective post-fire management and restoration priorities. The development of integrative models that account for both regenerated species composition and their corresponding ecophysiological processes is essential, as these models will refine forest management strategies, permitting more efficient conservation techniques and optimising restoration efforts to preserve biodiversity in the current context of increasing wildfire recurrence.

Technological and analytical innovation is at the heart of two other contributions that exemplify how advanced modelling techniques are transforming wildfire science. Tanase *et al*. (2025) integrate

LiDAR and optical data using artificial intelligence to estimate structural forest variables as proxies for fuel characterisation in Spain. Their results show that deep learning approaches can substantially improve predictive accuracy compared to traditional methods, although computational trade-offs remain considerable. This enhanced precision, however, comes with significant computational challenges. DL (Deep Learning) model training requires considerably more resources, demanding up to eight times the processing time of machine learning alternatives. Consequently, applying these models to large spatial extents (e.g., all of mainland Spain) or extended temporal periods is operationally constrained by these demands, which require substantial computational infrastructure. Borini Alves *et al*. (2025) provide a focused analysis of post-fire recovery in Amazonian savannas by integrating multi-year satellite time series with in situ fuel load measurements. Their findings reveal the adaptive capacity of these ecosystems and demonstrate the potential of harmonised Landsat and Sentinel-2 datasets for ecological monitoring. The fusion of these sensors enhanced temporal density, increasing the availability of cloud-free imagery by approximately 60% compared to Landsat-only inputs, thereby facilitating a more detailed assessment of spectral responses.

Rossini and Suárez (2025) situate wildfire research within the broader context of global change, employing climatic and spectral indices over nearly three decades to characterise fire regimes in the xerophytic shrublands of Argentina's Lihué Calel National Park. Their analysis underscores the tight coupling between climatic variability, vegetation productivity, and fire occurrence, reinforcing the need to integrate remote sensing and climate indicators to anticipate fire risk. This study demonstrates the applied utility of integrating specific climatic and ecological indices to enhance wildfire early warning systems in semiarid regions. The patterns identified between prolonged drought conditions, quantified by multi-scalar indices (SPEI-12, SPEI-24), and subsequent reductions in vegetation greenness (NDVI) offer a tangible methodology for anticipating periods of elevated fire susceptibility. These findings provide a mechanism to bridge ecological research with strategic land management and public policy.

Finally, Cobo *et al*. (2025) highlight the social dimension of wildfire resilience through the Plantando Cara al Fuego ("Facing the Fire") initiative. Using a service-learning approach, the project engages university students and local communities across Spain in prevention, restoration, and awareness activities, linking academic training with real-world environmental challenges. This contribution reminds us that addressing the wildfire crisis requires not only scientific innovation but also societal involvement, educational reform, and collective responsibility. The results from this investigation reinforce the significant potential of initiatives centred on innovative educational methodologies, specifically Service-Learning (ApS), to function as catalysts for change. These programs demonstrate an ability to generate positive societal responses that yield tangible benefits for the natural environment.

Overall, the works presented in this Special Issue provide valuable conceptual and methodological contributions to the scientific community by integrating ecological, technological, and social perspectives into the study of fire ecology. Innovations in remote sensing, spatial modelling, and multiscale analysis open new avenues for understanding wildfire patterns and trends under climate change scenarios. At the same time, approaches centred on restoration, governance, and public participation broaden the scope of fire science toward more preventive and adaptive management. Beyond synthesising recent advances in wildfire research, this Special Issue raises new questions about ecosystem resilience, the effectiveness of mitigation strategies, and the integration of scientific knowledge into decision-making and public policy. Its contribution, therefore, extends beyond the academic domain, serving as a reference point for future research and action in the global challenge of coexisting with fire.

We would like to express our sincere gratitude to all the authors who contributed their work to this Special Issue, as well as to the reviewers and the editorial team for their dedication and commitment throughout the evaluation and publication process. Their collective efforts have made this volume a valuable contribution to the advancement of integrated fire science and management.