Words into Action Guidelines:
National Disaster Risk Assessment
Hazard Specific Risk Assessment

6. Wildfire Hazard and Risk Assessment

Key words:
wildfires, wildfire hazard, risk assessment, wildfire exposure, wildfire vulnerability, risk mitigation, wildland-urban interface

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Globally, the occurrence of vegetation fires is common in all continents. Natural vegetation fires have been documented since prehistoric times and have significantly shaped the composition and dynamics of some ecosystems, including forests and open landscapes.

Since the beginning of land cultivation by early humans, the use of fire has contributed to the evolution of humanity and the formation and productivity of cultural landscapes. Today, the vegetated area annually affected by fire globally may range between 300 million and 600 million hectares (3 million-6 million square kilometres).[1]

While some natural ecosystems and land-use systems are dependent, adapted or tolerant to fire, other ecosystems are highly susceptible. With increasing human population and expanding land-use change, the interfaces between vegetation fires and vulnerable human assets are becoming more abundant, critical and conflicting.

And scientific evidence reveals that the indirect effects of vegetation fires have significant impacts on the environment and society. Most importantly, the fire emissions (gas and particle emissions) influence the composition of the atmosphere and thus affect the global climate, as well as human health and security.[2]

Wildfires in wildland-urban interfaces (WUIs) pose a serious threat to communities in many countries worldwide as they can be extremely destructive, killing people and destroying homes and other structures, as happened in California in 2003 and 2007, Greece in 2007, Australia in 2009, Israel in 2016 and Chile in 2017.[3,4,5,6] According to the fire fatalities database of the Global Fire Monitoring Center, an annual average of 297 fatalities caused by wildfires (both civilians and firefighters) was reported globally between 2008 and 2015.[7]

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1 Mouillot, F. and C. Field (2005). Fire history and the global carbon budget: A 1×1 fire history reconstruction for the 20th century. *Global Change Biology*, vol. 11, pp. 398-420.

2 Goldammer, J.G., ed. (2013). *Vegetation Fires and Global Change: Challenges for Concerted International Action*. A white paper directed to the United Nations and international organizations. Global Fire Monitoring Center publication. Remagen-Oberwinter: Kessel Publishing House. www.fire.uni-freiburg.de/latestnews/Vegetation-Fires-Global-Change-UN-White-Paper-GFMC-2013.pdf

3 Haynes, K. and others (2010). Australian bushfire fatalities 1900–2008: exploring trends in relation to the 'Prepare, stay and defend or leave early' policy. *Environmental Science & Policy*, vol. 13, pp. 185-194.

4 Mell, W.R. and others (2010). The wildland-urban interface fire problem – current approaches and research needs. *International Journal of Wildland Fire*, vol. 19, pp. 238-251.

5 For the wildfire situation in Israel in November 2016, see an exemplary report on WUI fires and damages:
www.chabad.org/news/article_cdo/aid/3503826/jewish/Damage-and-Destruction-as-75000-Return-Home-from-Raging-Fires-in-Israel.htm

6 For the wildfire situation in Chile in February 2017, see www.fire.uni-freiburg.de/GFMCnew/2017/01/20170125_cl.htm

7 Global Fire Monitoring Center, Global Wildland Fire Fatalities and Damages Annual Reports 2008-2015, GFMC / IWPM / UNISDR Global Wildland Fire Network Bulletins Nos. 13 to 21: www.fire.uni-freiburg.de/media/bulletin_news.htm

Wildfires also affect the ecological functioning of many ecosystems, as they partially or completely burn the vegetation layers and affect post-fire soil and vegetation processes such as soil erosion, debris flow, flooding and vegetation recovery.[8]

Figure 1 - Wildfire burning at the Wildland-Urban Interface

In addition to global impacts, fires also have serious local impacts, which are commonly associated with fire frequency and intensity, and imply loss of life and infrastructure, soil degradation, and changes in vegetation and biodiversity. These changes can also affect ecosystem services such as food production and stocks of fresh water or wood products. This process particularly affects tropical rain forest, which has little adaptability to fire.

Wildfire hazard assessment

The term "hazard" is considered a process, a phenomenon or a human activity that may cause loss of life, injury, or other health impacts, property damage, social and economic disruption or environmental degradation. Wildfire hazard is usually computed or expressed as potential fire behaviour (e.g. fireline intensity) or fuel physical and chemical properties (e.g. loading or biomass).

Land managers and firefighting officials need to consider the wildfire hazard potential in order to (a) identify local wildfire threats and assess the risks to communities, (b) educate and motivate homeowners and landowners and

8 Morgan, P. and others (2014). Challenges of assessing fire and burn severity using field measures, remote sensing and modeling. *International Journal of Wildland Fire*, vol. 23, pp. 1045-1060.

increase community involvement with wildfire awareness and preparation, (c) assist land managers and planners in making appropriate decisions about land management and development in fire-prone areas and (d) assist local fire protection districts in pre-attack planning.[9]

The spatial estimation of wildfire hazard can be difficult owing to the complexity of fire occurrence across multiple spatiotemporal scales.[10] The dominant factors determining wildfire behaviour, or the fire spread and intensity in space and time, are fuel availability and fuel conditions, topography, atmospheric conditions and the presence of firefighting. Wildfire hazard has been estimated through a variety of approaches considering some or several of these drivers, including expected fire behaviour, spatial arrangement of fuels, topography variables, and expert knowledge.

Wildfire Risk Assessment

Wildfire risk is the likelihood of a fire occurring, the associated fire behaviour, and the impacts of the fire. Risk mitigation is achieved when any of the three parameters (likelihood, behaviour and/or impacts) are reduced. Wildfire risk has been defined in a variety of ways. However, most of them refer only to wildfire likelihood and behaviour and do not take into consideration the expected fire impacts.[11,12,13,14]

Recent advances in landscape wildfire behaviour modelling have led to a number of new tools and approaches for applying risk frameworks to wildfire management problems which allow land managers to estimate all of the above-mentioned primary wildfire risk components to a number of high-value resources located within forest stands and lands.

Computer models can now perform spatially explicit fire simulations over heterogeneous fuels and map wildfire behaviour characteristics across large landscapes. These approaches have been recently incorporated as a key element for assessing risk in wildfire management in the United States[15] on a

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9 Calkin, D.E. and others (2011). A comparative risk assessment framework for wildland fire management: the 2010 cohesive strategy science report. *General Technical Report RMRS-GTR* 262. United States Department of Agriculture Forest Service Rocky Mountain Research Station.

10 Keane, R. and J. Menakis (2014). Evaluating wildfire hazard and risk for fire management applications. Making *Transparent Environmental Management Decisions* (K. Reynolds, P. Hessburg and P. Bourgeron, eds.), 111-135. New York: Springer.

11 Hardy, C. (2005). Wildland fire hazard and risk: roblems, definitions, and context. *Forest Ecology and Management*, vol. 211, 73-82.

12 Chuvieco, E. and others (2012). Integrating geospatial information into fire risk assessment. *International Journal of Wildland Fire*, vol. 2, pp. 69-86.

13 Blanchi R., M. Jappiot and Alexandrian D. (2002). Forest fire risk assessment and cartography. A methodological approach. In: Viegas, D., ed. *Proceedings of the IV International Conference on Forest Fire Research.* Luso, Portugal.

14 Carmel, Y. and others (2009). Assessing fire risk using Monte Carlo simulations of fire spread. *Forest Ecology and Management*, vol. 257, pp. 370-377.

15 Scott, J., M. Thompson and D. Calkin (2013). A wildfire risk assessment framework for land and resource management. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, *General Technical Report RMRS-GTR 315.*

national scale and in Euro-Mediterranean countries on a regional scale.[16] They are also used to support tactical and strategic decisions related to the mitigation of wildfire risk, the post-fire impacts, the forest carbon pools estimation, the forest restoration, and the post-fire soil erosion.

Wildfire Exposure and Vulnerability

Wildfire exposure defines the situation of people, infrastructure, housing, production capacities and other tangible human assets located in wildfire-prone areas.[17] Wildfire exposure is simply the spatial juxtaposition of wildfire likelihood and intensity metrics with the location of Highly Valued Resources and Assets (HVRAs) found in a specific area. Wildfire vulnerability expresses the potential damage from wildfires and it may be defined as: "The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging impacts of a hazard".[18] The assessment of vulnerability to wildfire should consider the expected damage caused by wildfire, which is a critical part of an integrated wildfire risk assessment.

The combination of wildfire exposure, vulnerability and risk assessment has been widely used as an integrated framework for holistic fire management in many fire-prone parts in the world. [19, 20, 21, 22]

Recently, the concepts of wildfire risk transmission and human and natural systems have been studied in the United States in order to create assessment methods that can advance concepts for cross-boundary wildfire risk governance and facilitate the development of more effective policies and practices for fire-prone landscapes.[23, 24]

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16 Mitsopoulos, I., G. Mallinis and M. Arianoutsou (2015). Wildfire risk assessment in a typical Mediterranean Wildland–Urban Interface of Greece. *Environmental Management,* vol. 55, pp. 900-915.

17 Fairbrother, A. and Turnley, J. (2005). Predicting risks of uncharacteristic wildfires: application of the risk assessment process. *Forest Ecology and Management*, vol. 211, pp. 28-35.

18 United Nations Office for Disaster Risk Reduction (UNISDR) (2009). UNISDR terminology on disaster risk reduction. Available from www.unisdr.org/we/inform/terminology

19 Calkin, D.C. and others (2011). Progress towards and barriers to implementation of a risk framework for US Federal wildland fire policy and decision making. Forest Policy and Economics, vol.13, pp. 378-389.

20 Acuna, M.A. and others (2010). Integrated spatial fire and forest management planning. Canadian Journal of Forest Research, vol. 40, pp. 2370-2383.

21 Alcasena, F.J., M. Salis and C. Vega-García (2016). A fire modeling approach to assess wildfire exposure of valued resources in central Navarra, Spain. European Journal of Forest Research, vol. 135, pp. 87-107.

22 Plucinski, M. and others (2017). Improving the reliability and utility of operational bushfire behaviour predictions in Australian vegetation, *Environmental Modelling & Software*, vol. 91, pp. 1-12.

23Ager, A. and others (2017). Network analysis of wildfire transmission and implications for risk governance. PLOS ONE 12 (3): e0172867.

24 Spies, T. A. and others (2014). Examining fire-prone forest landscapes as coupled human and natural systems. Ecology and Society, vol. 19, No. 3, art. 9.

Risk Assessment and Use in National DRR measures

A critical component of effective wildfire prevention policies and strategies is a long-term wildfire risk assessment, based on robust methods accounting for the spatial and temporal nature of wildfire risk.[25, 26] On a local scale, such wildfire risk assessment could be used for areas to be treated for wildfire risk reduction, fuel treatment practices implementation, fire towers and water tank construction. This information is extremely useful in implementing efficient preventive strategies and measures, since fire prevention is not only preferable but also a cost-effective way to manage forest fires when compared to fire fighting and suppression. Availability of information on wildfire risk assessment on a regional scale supports optimal allocation of fire-fighting personnel and the protection of critical infrastructure.[27]

Holistic wildfire management and implementation plans at landscape level should be based on wildfire risk scenarios that take into consideration wildfire danger warning systems, coupled with physical and socioeconomic parameters.[28]

For global scale wildfire risk assessment, the focus is shifted towards identifying supra-national patterns of similarities and differences, developing and coordinating effective prevention and response mechanisms, identifying areas where more detailed risk assessment models should be implemented, and facilitating research on the context of climate change. Global wildfire risk assessment also is necessary for comprehensive wildfire protection and policy development.

A Regional Case Study

Wildfires constitute a severe threat to cultural heritage and archaeological sites, particularly in countries where most of these sites are covered with vegetation or situated close to forests and other flammable vegetation. Reports of damage caused to historical sites by wildfires are becoming more frequent and alarming. Wildfire events in recent years have threatened UNESCO Natural World Heritage Properties in recent years, including Garajonay National Park (Canary Islands, Spain), Nea Moni Monastery (Chios Island, Greece), Olympia (Greece), and Laurisilva (Madeira Island, Portugal).

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25 Chuvieco, E. and others (2010). Development of a framework for fire risk assessment using Remote Sensing and Geographic Information System technologies. *Ecological Modelling*, vol. 221, pp. 46-58.

26 Jones, T. and others (2012). Quantitative bushfire risk assessment framework for severe and extreme fires. *Australian Meteorological and Oceanographic Journal*, vol. 62, pp.171-178.

27 Kalabokidis, K. and others (2012). Decision support system for forest fire protection in the Euro-Mediterranean region. *European Journal of Forest Research*, vol. 131, pp. 597-608.

28 Morgan, P., Hardy, C.C., Swetnam, T.W., Rollins, M.G. and Long, D.G. (2001). Mapping fire regimes across time and space: understanding coarse and fine-scale fire patterns. International Journal of Wildland Fire, vol. 10, pp. 329-342.

In 2016, a regional wildfire risk and exposure assessment was carried out at Mount Athos in Greece, a UNESCO World Heritage Site. This case study is an example of the use of satellite remote sensing and geographic information system (GIS) for wildfire risk assessment on a regional and local scale (Figure 1).[29]

The special characteristics of the surroundings, the monasteries and their architecture, the relatively limited human activity, and the singular and isolated location of the peninsula have combined to make Mount Athos one of the most unique and important coastal landscapes in Greece and the Mediterranean area as a whole. Mount Athos includes 20 monasteries and other structures that are threatened by increasing frequency of wildfires. Assessing wildfire risk and exposure enabled fire management plans to be developed and implemented for this region, supporting the management of its important cultural heritage.

The study resulted in (a) the development of detailed site-specific fuel models in a Mediterranean study area which are suitable for fire behaviour prediction; (b) the production of a detailed fuel-type map with the use of high spatial and temporal resolution remote sensing data processed through an object-based classification approach and (c) the generation of accurate fire-risk and exposure maps in a fragmented landscape.

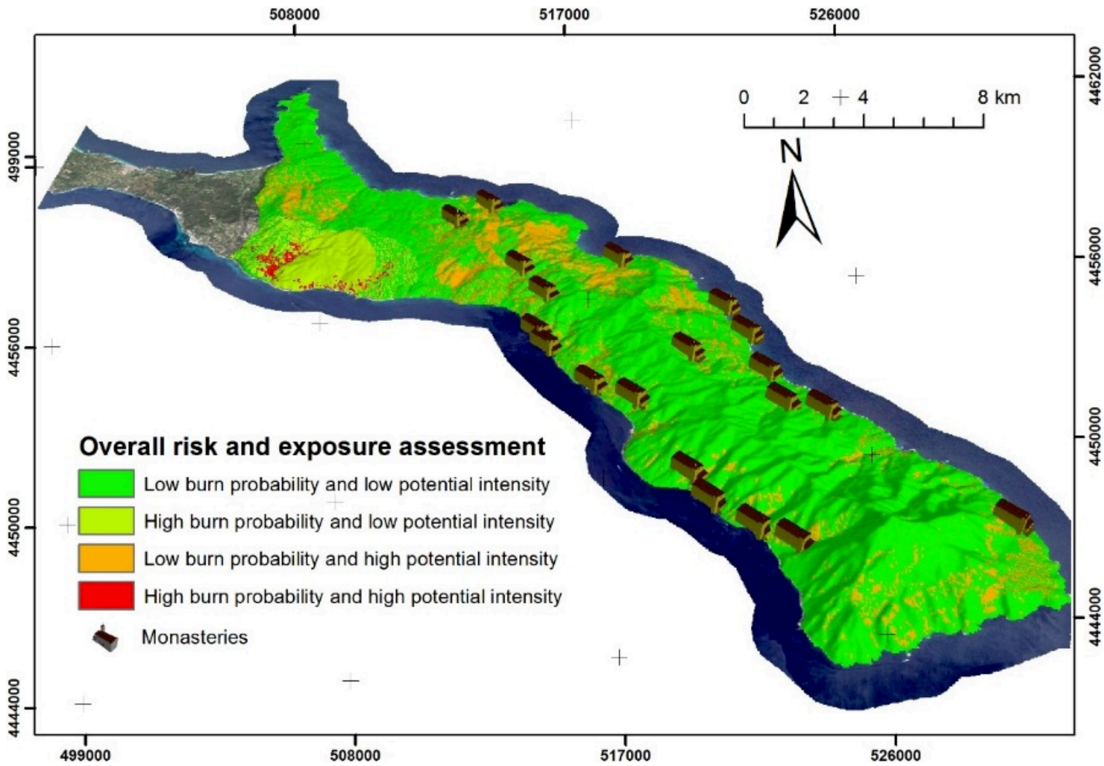

Figure 2 - Fire risk and exposure assessment at Mount Athos, Greece

29 Mallinis, G. and others (2016). Assessing wildfire risk in cultural heritage properties using high spatial and temporal resolution satellite imagery and spatially explicit fire simulations: the case of Holy Mount Athos, Greece. Forests, vol. 7, issue 2.

Resources for Further Information

Freely available software tools exist for simulating wildfire propagation and wildfire impacts on different temporal and spatial scales. Some widely used models include BehavePlus, FlamMap, FARSITE and FOFEM. These models require appropriate skills, training and adequate knowledge of GIS and wildland fuel modelling to be used effectively. Most of the software and tools have been validated against prescribed fires and medium-low intensity wildfires.

Relevant information about models and the software tools can be found through the Fire, Fuel, and Smoke Science Program web portal.[30] ArcFuels is a streamlined fuel management planning and wildfire risk assessment toolbar implemented in ArcMap GIS software that creates a trans-scale (stand to large landscape) interface to apply various forest growth (e.g. Forest Vegetation Simulator) and fire behaviour models (e.g. FlamMap).[31]

Methods for enhancing capacities of local communities in wildfire disaster risk reduction are provided by numerous initiatives.[32] The FireWise USA community programme is a collaborative approach that encourages local solutions for safety by involving homeowners in taking individual responsibility for protecting their homes against the threat of wildfire.[33] FireSmart is a Canadian initiative that provides to communities and individuals across Canada the information and tools they need to confront interface fire protection issues.[34]

The Global Fire Monitoring Center (GFMC) provides a global portal for wildland fire documentation, information and monitoring and is publicly accessible through the internet.[35] The regularly updated national to global wildland fire products of GFMC are generated by a worldwide network of cooperating institutions.

Web-based information and GFMC services include:

- Early warning of fire danger and near-real time monitoring of fire events, including the Global Wildland Fire Early Warning System.[36]
- Interpretation, synthesis and archive of global fire information.
- Support of countries and international organizations to develop long-term strategies or policies for wildland fire management, including community-

30 Rocky Mountain Research Station Fire Sciences Laboratory www.firelab.org

31 Software and functional tutorial www.fs.fed.us/wwetac/tools/arcfuels/

32 Portal of global initiatives in participatory/community-based fire management www.fire.uni-freiburg.de/Manag/CBFiM.htm

33 FireWise community programme http://firewise.org/

34 FireSmart Canada www.firesmartcanada.ca/

35 www.fire.uni-freiburg.de

36 www.fire.uni-freiburg.de/gwfews/index.html

based fire management approaches and advanced wildland fire management training for decision makers, especially in preventing and preparing for wildfire disasters.

- Serve as advisory body to the United Nations system through the coordination of the UNISDR Wildland Fire Advisory Group and the UNISDR Global Wildland Fire Network.[37]
- Emergency hotline and liaison capabilities for providing assistance for rapid assessment and decision support in response to wildland fire emergencies under cooperative agreements with the Emergency Services Branch of the United Nations Office for the Coordination of Humanitarian Affairs.[38]

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37 www.fire.uni-freiburg.de/GlobalNetworks/globalNet.html

38 www.fire.uni-freiburg.de/emergency/un_gfmc.htm