4th Intercontinental Geoinformation Days

igd.mersin.edu.tr

# Fire vulnerability of Hyrcanian forests (FVHF): A conceptual framework for an enhanced forest fire risk management in northern Iran

**Elnaz Nejatiyanpour [1,2], Omid Ghorbanzadeh [3], Josef Strobl [2], Mahmoud Daneshvar Kakhki [1], Hamid Amirnezhad [4], Mahmoud Sabouhi Sabouni[*1]**

[1]*Ferdowsi university of Mashhad, Faculty of Agriculture, Department of Agricultural Economics, Mashhad, Iran*
[2] *University of Salzburg, Department of Geoinformatics—Z_GIS, 5020 Salzburg, Austria*
[3] *Institute of Advanced Research in Artificial Intelligence (IARAI), Landstraßer Hauptstraße 5,1030 Vienna, Austria*
[4]*Sari Agricultural Sciences and Natural Resources University, Faculty of Agricultural Engineering, Department of Agricultural Economics, Sari, Iran*

**Keywords**
GIS
Forest fire vulnerability
Socio-economic indicators
Adaptive capacity index
Exposure index

**ABSTRACT**

Recently, increasing forest fires have contributed to deforestation and desertification in the Hyrcanian forests in northern Iran. It is crucial to consider the complex interactions of forest fires with particularities of the environment and the social and economic factors. This study introduces a conceptual approach to developing a comprehensive forest fire vulnerability index using both quantitative and qualitative methods. The indicators can be grouped into the three components of vulnerability (exposure, sensitivity, and adaptive capacity) based on three categories (social, economic, and environmental), resulting in three indexes: Forest Fire Exposure Index (FEI), Forest Fire Sensitivity Index (FSI) and Forest Fire Adaptive Capacity Index (FACI). Finally, we can create an integrated Forest Fire Vulnerability Index (FVI). The most vulnerable areas to forest fires can be mapped using remote sensing data, geographic information systems (GIS), the statistical data available at the Forests, Range & Watershed Management Organization (FRWO), and machine learning models. By localizing the input data and socio-economic indicators, the methodology is transferrable to other regions and helps forest fire management and prevention planning.

## 1. Introduction

Forest fires are a natural hazard that can begin and spread immediately and uncontrollably, causing significant losses and damages(Piralilou et al., 2022) In general, natural reasons such as lightning cause just around 4% of forest fires worldwide. In all other cases, forest fires result from human action, whether it is intentional or unintentional (Peter Hirschberger, 2016) Forest fires are not only an environmental problem but also have significant economic and social impacts, affect the quantity and quality of the forest's goods and services, and create a considerable problem related to both private owners for revenue damage and public owners for ecosystem service damage(Fagarazzi et al., 2021; Gonzalez-Caban, 2007) The forest fire also affects urban areas, infrastructure networks, power lines, agricultural regions, and civic society. People can lose their lives or become ill, and communities can suffer from decreased well-being and economic decline due to forest fires(Mavsar et al., 2010) Moreover, both residential neighborhoods and the tourism industry are negatively impacted by forest fires. In the Western Region United States, the primary fire season intercepts the peak summer tourist season and becomes a significant problem for the demand and supply of tourism sectors(Brown et al., 2008; Thapa et al., 2013) For instance, wildfires are an annual concern in Florida, affecting residents and visitors. In addition to Colorado, a tourism-dependent city, Mesa Verde National Park, a popular tourist destination, was closed because of the forest fire. Similar impacts have been seen in California, Arizona, Nevada, New Mexico, Texas, Washington, and Utah (Thapa et al., 2013).

Also, In Europe, the economic losses of forest fires in the 2000-2017 period are over EUR 54 billion, around EUR 3 billion. For example, the Tuscan Region (Central Italy) spends around 12 million euros on forest fire

* **Corresponding Author**

(nejatianpour84@mail.um.ac.ir) ORCID ID 0000-0001-5539-3882
(omid.ghorbanzadeh@iarai.ac.at) ORCID ID 0000-0002-9664-8770
(Josef.Strobl@sbg.ac.at) ORCID ID 0000-0001-6234-9812
(daneshvar@um.ac.ir) ORCID ID 0000-0003-3063-3418
(h.amirnejad@sanru.ac.ir) ORCID ID 0000-0002-4307-1146
*(sabouhi@um.ac.ir) ORCID ID 0000-0002-0454-0368

**Cite this study**

Nejatiyanpour E, Ghorbanzadeh O, Strobl J, Daneshvar Kakhki M, Amirnezhad, H & Sabouhi Sabouni M (2022). Socio-economic and environmental wildfire vulnerability of Hyrcanian forests, Northern Iran. 4th Intercontinental Geoinformation Days (IGD), page numbers, Mersin, Turkey

prevention and control every year (Viccaro & Caniani, 2019) The economic effect on Greece, Spain, France, Italy, and Portugal may increase to over EUR 5 billion per year by 2070-2100 due to rapid economic growth and increased greenhouse gas emissions (Rego et al., 2018).

Therefore, the socio-economic impacts of forest fires should be evaluated as an essential part of the fire risk assessment, forest fire policy development, and management practices planning and implementation(Morton et al., 2003) And the climate, environmental, and ecological factors aren't the only factors to consider for prevention and mitigation efforts in wildfire-prone areas (de Diego et al., 2019) Despite the importance of socio-economic factors on forest fire vulnerability for budget optimization and decision-making, few studies explicitly examined socio-economic factors mixed with environmental factors.

Furthermore, a lot of research has been conducted to determine socio-economic vulnerability. The IPCC 's concept and framework of vulnerability were often used as the basis for their evaluations, where vulnerability is defined by exposure, sensitivity to perturbations or external pressures, and the capacity to adjust or adapt(Adger, 2006; Sharma & Ravindranath, 2019) (see Figure 1).

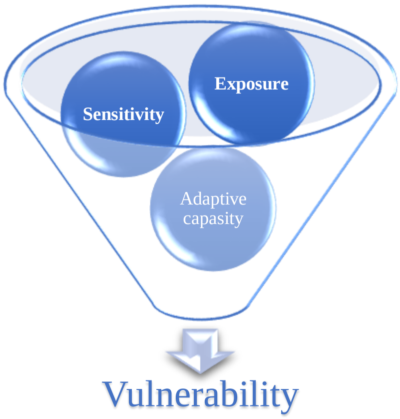


**Figure 1.** The concept of vulnerability

Where, exposure is the nature and the degree to which a system is pressured by environmental or sociopolitical factors. Sensitivity is how a system is modified or impacted by perturbations. Adaptive capacity is the ability of a system to evolve in order to accept environmental threats or policy changes, as well as to increase the range of variability with which it can adapt(Adger, 2006) This vulnerability concept has been used in the vulnerability to heat-related phenomena (Grigorescu et al., 2021)In contrast, this framework of vulnerability in forest fire vulnerability is less addressed. The novelty of our study is developing a comprehensive Forest Fire Vulnerability Index (FVI) based on three main components of vulnerability and creating the Forest Fire Exposure Index (FEI), Forest Fire Sensitivity Index (FSI), and Forest Fire Adaptive Capacity Index (FACI) considering three categories; social, economic, and environmental factors, as well as producing the final forest fire vulnerability map.

## 2. Method

### 2.1. Study area

The Hyrcanian Forests World Heritage property stretch 850 km along the southern coast of the Caspian Sea and covers around 7% of remnant Hyrcanian forests in Iran (Figure 2). These ancient forests are important refugia and the world's only remaining temperate deciduous broadleaved forests Ramezani et al., 2008).

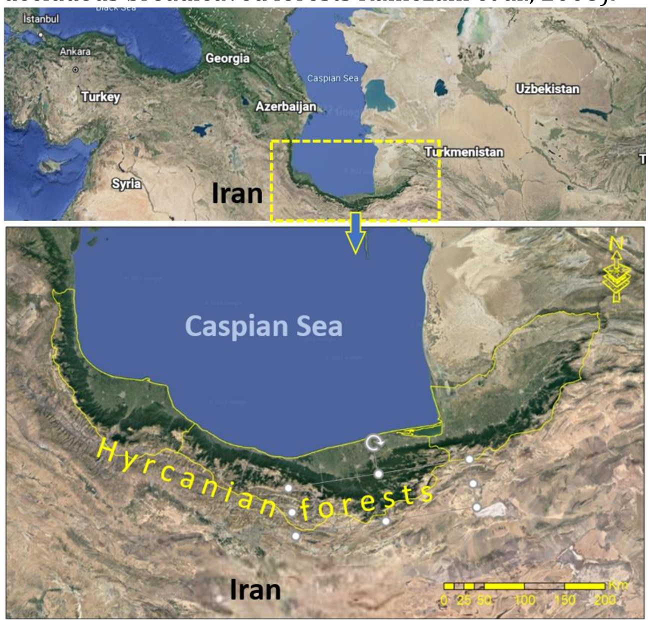


**Figure2.** The Hyrcanian Forests in Iran

In the northern part of Iran, most forest fires happen on the ground surface and mainly damage young trees(Jahdi et al., 2014) As a result, regeneration is seriously impacted, and forest fires are among the most common causes of deforestation and desertification in Iran (Ghorbanzadeh et al., 2019) Although forest fires frequently happen in the Hyrcanian forests of Iran (Ghorbanzadeh et al., 2019) and have caused enormous economic and ecological losses (Adab et al., 2021) There is not a comprehensive study about fire forest vulnerability considering socio-economic and environmental factors. It is appropriate and necessary to analyze the forest fire vulnerability of the Hyrcanian forest.

### 2.2. Research methods

Using an empirical approach, the current study assesses socio-economic and environmental forest fire vulnerability. The indicators are chosen and ranked based on their relevance to forest fires, expert judgment, and database availability and accuracy. We consider the various characteristics of vulnerability components to index construction. For instance, wildfires are caused by a combination of social and economic factors with natural factors(de Diego et al., 2021). Accordingly, these factors must be considered in indexing forest fire exposure. Furthermore, economic and environmental factors increase the vulnerability to the impacts of hazards (de Diego et al., 2019) Therefore, sensitivity and adaptive capacity, two other vulnerability components, are the characteristic determined by these factors (see Figure 3).

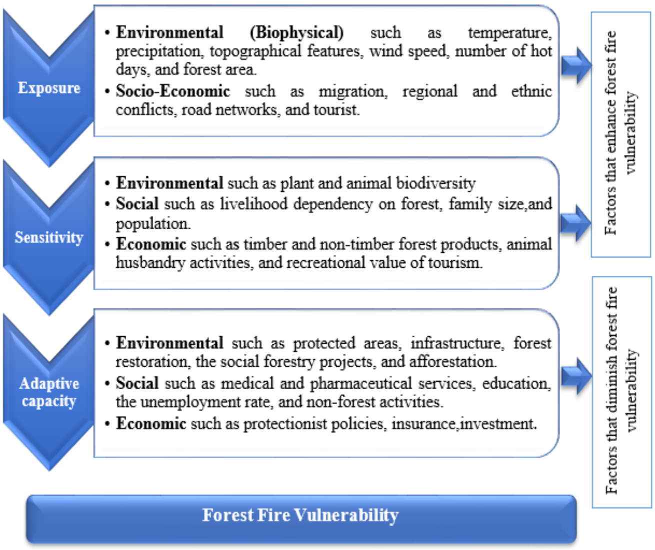


**Figure 3.** Framework for assessing the forest fire vulnerability

The current methodology may be applied to any region damaged by forest fires. The statistical data used in the current research, remote sensing data, geographic information systems (GIS), and the statistical data available at the Forests, Range & Watershed Management Organization (FRWO). The FVI was developed over a multi-stage sequential process that involved:

### 2.2.1. Selection of indicators

The indicators have been considered to investigate the various components of forest fire vulnerability. For the current study, the selected indicators are based on the previous studies approaching the general issues of natural hazards vulnerability (Grigorescu et al., 2021;) orfire forest vulnerability studies (Sadowska et al., 2021)in particular. The validation of indicators can be made using the expert judgment approach.

### 2.2.2. Data normalization

Because the variables of the statistical indicators are generated using various measuring units, this is an essential process.

### 2.2.3. Integrating the indexes into a single index

Develop a comprehensive forest fire vulnerability index by combining the Forest Fire Exposure Index (FEI), Forest Fire Sensitivity Index (FSI), and Forest Fire Adaptive Capacity Index (FACI).

$$FVI = f\ (FEI, FSI, FACI)$$

### 2.2.4. Forest fire vulnerability mapping

Machine learning (ML) approaches can use for mapping the forest fire vulnerability of the Hyrcanian forest. Machine learning approaches have been applied to analyze natural disasters during the last two decades(Ghorbanzadeh et al., 2019; ).

## 3. Results

The spatial prediction of forest fire vulnerability for Heyrcanian can be made using state of the art ML approaches by applying the relevant conditioning factors, and the fire inventory data set. The resulting forest fire vulnerability maps measure the probability of a wildfire occurrence. Also, considering economic analysis as an integral part of proactive fire forests management leads to better-informed decisions and selecting the most effective options in a particular circumstance. Moreover, forest fire risk mapping is used for identifying locations in which a probability of loss is determined from assessments of socio-economic forest fire vulnerability.

## 4. Discussion

The development of an integral vulnerability index is defective without considering economic factors. We introduce a novel framework for fire forest vulnerability based on three groups of factors (socio-economic and environmental) by considering exposure, sensitivity, and adaptive capacity as vulnerability components. The results of our study by assessments of socio-economic forest fire vulnerability can help policymakers with forest fire management and lead to making better-informed decisions and selecting the most effective options in a particular circumstance. Additionally, the final forest fire vulnerability map can be used to identify areas with a high probability of loss and require prevention planning.

## 5. Conclusion

The current methodology for developing the FVI based on three main components of vulnerability and considering social, economic, and environmental factors is transferrable to other regions where localizing the input data may be applied to any region damaged by wildfire.

## Acknowledgement

The authors are grateful for the support of the University of Salzburg, and the Institute of Advanced Research in Artificial Intelligence (IARAI) GmbH, Vienna, Austria.

## References

Adab, H., Kanniah, K. D., & Solaimani, K. (2021). Remote sensing-based operational modeling of fuel ignitability in Hyrcanian mixed forest, Iran. *Natural Hazards*, *108*(1), 253–283. https://doi.org/10.1007/s11069-021-04678-w

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Brown, R. N. K., Rosenberger, R. S., Kline, J. D., Hall, T. E., & Needham, M. D. (2008). Visitor preferences for managing wilderness recreation after wildfire. *Journal of Forestry*, *106*(1).

de Diego, J., Rúa, A., & Fernández, M. (2019). Designing a Model to Display the Relation between Social Vulnerability and Anthropogenic Risk of Wildfires in Galicia, Spain. *Urban Science*, *3*(1). https://doi.org/10.3390/urbansci3010032

de Diego, J., Rúa, A., & Fernández, M. (2021). Vulnerability variables and their effect on wildfires in galicia (Spain). a panel data analysis. *Land*, *10*(10). https://doi.org/10.3390/land10101004

Fagarazzi, C., Fratini, R., Montanino, M., Viccaro, M., Cozzi, M., Romano, S., & Riccioli, F. (2021). The economic value of fire damages in Tuscan agroforestry areas. *IForest*, *14*(1), 41–47. https://doi.org/10.3832/ifor3607-013

Ghorbanzadeh, O., Blaschke, T., Gholamnia, K., & Aryal, J. (2019). Forest fire susceptibility and risk mapping using social/infrastructural vulnerability and environmental variables. *Fire*, *2*(3). https://doi.org/10.3390/fire2030050

Gonzalez-Caban, A. (2007). Wildland Fire Management Policy and Fire Management Economic Efficiency in the USDA Forest Service. *IV International Wildland Fire Conference*, *May*.

Grigorescu, I., Mocanu, I., Mitrică, B., Dumitraşcu, M., Dumitrică, C., & Dragotă, C. S. (2021). Socio-economic and environmental vulnerability to heat-related phenomena in Bucharest metropolitan area. *Environmental Research*, *192*. https://doi.org/10.1016/j.envres.2020.110268

Jahdi, R., Darvishsefat, A. A., Etemad, V., & Mostafavi, M. A. (2014). Wind effect on wildfire and simulation of its spread (Case study: Siahkal forest in northern Iran). *Journal of Agricultural Science and Technology*, *16*(5).

Mavsar, R., González-Cabán, A., & Farrera, V. (2010). *The importance of economics in fire management analysis* (J. Sande Silva, F. Rego, P. Fernandez, & E. Rigolot, Eds.). European Forest Institute.

Morton, D. C., Roessing, M. E., Camp, A. E., & Tyrrell, M. L. (2003). *Assessing the Environmental, Social, and Economic Impacts of Wildfire*. www.yale.edu/gisf

Peter Hirschberger, 4con forestconsulting, www.forestconsulting.de. (2016). *2017 STUDY FORESTS ABLAZE Causes and effects of global forest fires*. www.forestconsulting.de

Piralilou, S. T., Einali, G., Ghorbanzadeh, O., Nachappa, T. G., Gholamnia, K., Blaschke, T., & Ghamisi, P. (2022). A Google Earth Engine Approach for Wildfire Susceptibility Prediction Fusion with Remote Sensing Data of Different Spatial Resolutions. *Remote Sensing*, *14*(3). https://doi.org/10.3390/rs14030672

Ramezani, E., Marvie Mohadjer, M. R., Knapp, H. D., Ahmadi, H., & Joosten, H. (2008). The late-Holocene vegetation history of the Central Caspian (Hyrcanian) forests of northern Iran. *Holocene*, *18*(2). https://doi.org/10.1177/0959683607086768

Rego, F. M. C. C., Manuel Moreno, J., Vallejo Calzada, V. R., & Xanthopoulos, G. (2018). FOREST FIRES — Sparking firesmart policies in the EU. *European Commission*. https://doi.org/10.2777/248004

Sadowska, B., Grzegorz, Z., & Stępnicka, N. (2021). Forest fires and losses caused by fires – an economic approach. *WSEAS Transactions on Environment and Development*, *17*, 181–191. https://doi.org/10.37394/232015.2021.17.18

Thapa, B., Cahyanto, I., Holland, S. M., & Absher, J. D. (2013). Wildfires and tourist behaviors in Florida. *Tourism Management*, *36*. https://doi.org/10.1016/j.tourman.2012.10.011

Viccaro, M., & Caniani, D. (2019). Forest, Agriculture, and Environmental Protection as Path to Sustainable Development. In *Natural Resources Research* (Vol. 28). https://doi.org/10.1007/s11053-019-09497-2