engineering proceedings

MDPI

Proceeding Paper

Assessment and Analysis of Forest Fires in Bulgaria †

Rositsa Velichkova [1,*], Elitsa Gieva [2] and Iskra Simova [1]

[1] Department of Hydroaerodynamics and Hydraulic Machines, Technical University of Sofia, 1756 Sofia, Bulgaria; isimova@tu-sofia.bg
[2] Department of Microelectronics, Technical University of Sofia, 1756 Sofia, Bulgaria; gieva@tu-sofia.bg
* Correspondence: rvelichkova@tu-sofia.bg
† Presented at the 4th International Conference on Communications, Information, Electronic and Energy Systems (CIEES 2023), Plovdiv, Bulgaria, 23–25 November 2023.

Abstract: Forest fires exert detrimental effects on the economic, social, and ecological well-being of both individual nations and expansive geographical regions. These fires lead to the destruction of substantial quantities of valuable timber, the degradation of forest plantations, extensive deforestation, a decline in the protective functions of forests, diminished effectiveness in safeguarding water resources, and heightened soil erosion, particularly in mountainous terrain. Concurrently, agricultural production faces deteriorating conditions, and both wildlife and human populations, along with their production facilities, residences, infrastructure, and other assets, become exposed to significant hazards as a direct or indirect consequence of these raging infernos. The data that are used and analysed are for the period 1980–2018.

Keywords: forest fire; assessment; pollution

1. Introduction

Forest fires rank among the most intricate and prevalent natural disasters. They have the capacity to engulf vast expanses, often infiltrating remote and challenging terrains, thereby compounding the already formidable task of extinguishing them. In recent years, these fires have emerged as a principal concern affecting both our nation and the global community. Alarming statistics underscore the growing frequency with which these fires spiral beyond containment. Consequently, the affected regions witness escalating devastation in terms of burnt acreage, material losses, and environmental contamination. The evolving landscape of forest fires presents a pressing challenge for communities and nations alike [1].

A recent forest fires analysis reveals that they occur most often in the foothills, where forests alternate in close proximity with cereal crops. The intensive movement of people and equipment in these areas during harvesting and fodder, the throwing of unextinguished matches and cigarettes, the use of open fire for various purposes and the burning of stubble without prior precautions are the prerequisites for ignitions and for carrying the fire in the forest massifs [2–4]. In addition to large losses of valuable wood, forest fires also cause hard-to-recover damage to the environment: a significant amount of harmful substances are released into the atmosphere, oxygen generation decreases, soils are destroyed, and flora and fauna are irreparably damaged.

In recent years, there has been a drastic increase in fires worldwide. Our country is no exception. There is no single methodology for effectively fighting forest fires, which makes the subject of forest fires and the protection of forest areas very relevant.

In the presented work, a methodology is given for determining the rate of fires by region in Bulgaria, and how the amount of carbon dioxide released during forest fires is determined for coniferous and broad-leaved forests.

check for updates

Citation: Velichkova, R.; Gieva, E.; Simova, I. Assessment and Analysis of Forest Fires in Bulgaria. *Eng. Proc.* **2024**, *60*, 2. https://doi.org/10.3390/engproc2024060002

Academic Editor: Renato Filjar

Published: 5 January 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

2. Analysis of Risk Assessment of Forest Fires

The assessment of the risk level of forest fires in the forested areas of the country is conducted following the guidelines established in reference [5], following this specific sequence:

The concentration of forest fires in forested region within a country, denoted as R_d, is determined as follows:

$$R_{d.} = \frac{1000\sum_{i=1}^{n} N_i}{n \times F_{t.}}, \quad (1)$$

where R_d. is the average value of the fires for forest region per year (units/year/1000 ha); Ni is the number of fires (units/year); n is the number of years for the analysed period (n = 10); and F_t. is the total country forest area (ha).

With the help of Equation (2), the inflammability of the forest regions can be calculated as an estimate of the burned areas for the period:

$$R_{ra.} = \frac{1000\sum_{i=1}^{n} F_{ba.}}{n \times F_t}, \quad (2)$$

where R_{ac}. is the average value for the actual combustibility of the country forest territory for 1 year (ha/year/1000), ha; and F_{ba}. the annual burnt area in the country forest territory (ha/year).

The magnitude of the risk of forest fires, denoted as R_{rf}, is determined as an integrated indicator, incorporating the numerical values for R_d—the density of forest fires and R_{ac}—the real inflammability of forest territories, using the following formula:

$$R_{rf} = R_{d.} \times R_{ac.} \quad (3)$$

The methodology shown in Figure 1 shows the risk of forest fires by region in the territory of Bulgaria.

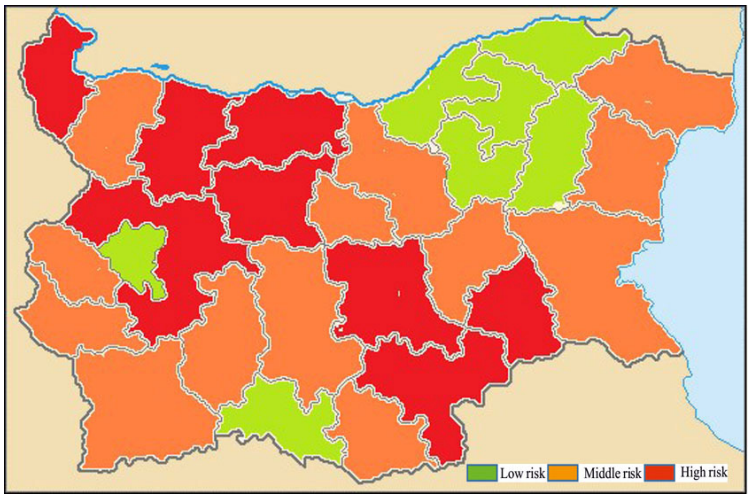

Figure 1. Fire risk by districts in Bulgaria.

Figure 1 shows the distribution of fires by area. It can be seen that the high risk areas are like those shown based on the statistics in the next part.

3. Calculation of the Amount of Carbon Dioxide Released

In this section, calculations have been made of the amounts of carbon dioxide released during forest fires for the last two years. The calculations were made for broadleaf and coniferous forests and were divided by the regions of Bulgaria. Figures 2–5 shows the burned areas by region in Bulgaria for 2021 and 2022, and they are divided into broadleaved and coniferous forests.

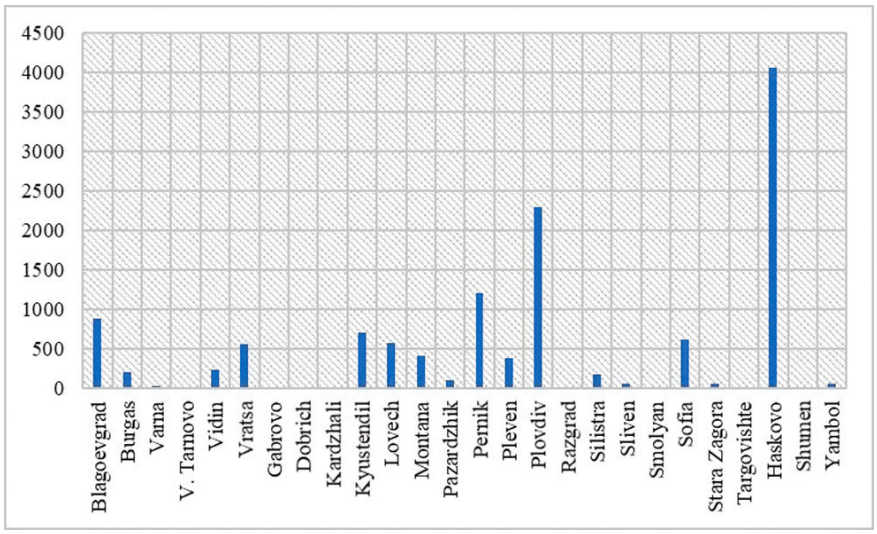

Figure 2. Distribution of forest fires for deciduous forests for 2021.

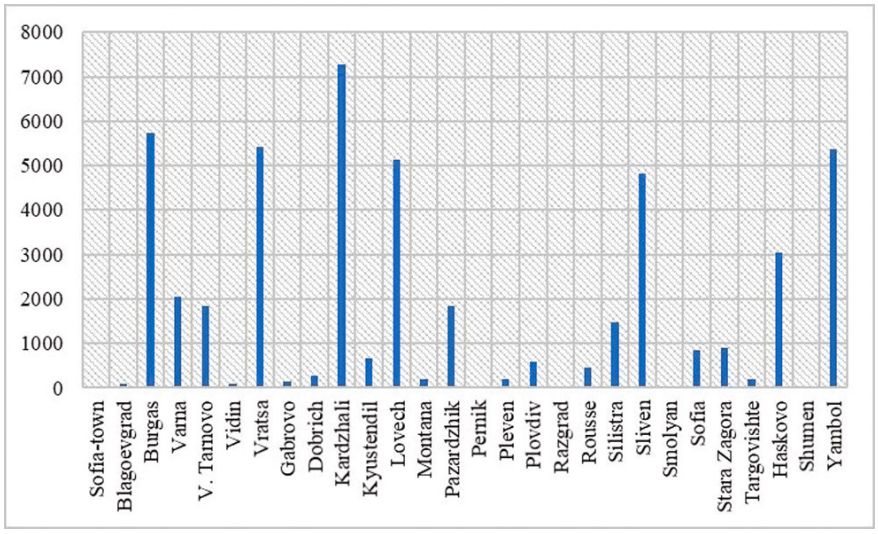

Figure 3. Distribution of forest fires for deciduous forests for 2022.

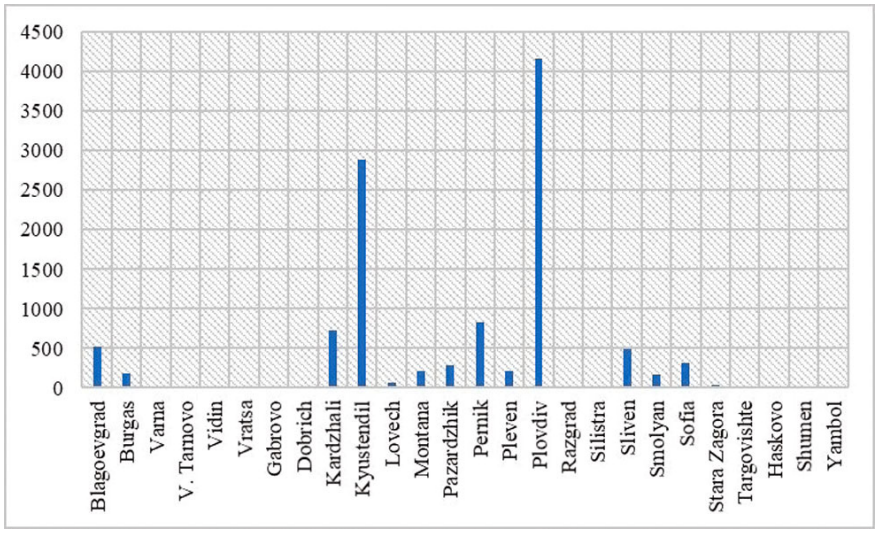

Figure 4. Distribution of forest fires for coniferous forests for 2021.

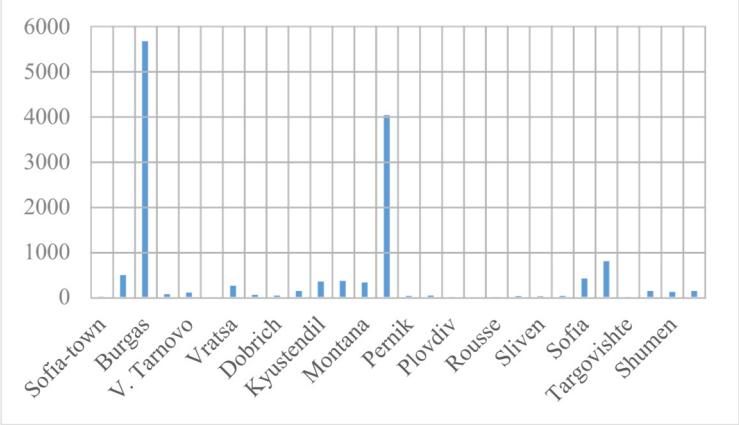

Figure 5. Distribution of forest fires for coniferous forests for 2022.

Depending on the year and the location of the fires, the following dependence is observed, that there are more fires in broad-leaved forests than in coniferous forests. This can be explained by the fact that there are more broadleaf forests in the territory of Bulgaria, and they are also more accessible to humans than coniferous forests, and can be further explained by the fact that most fires occur as a result of human error.

Forest fires represent a complex mixture of chemical compounds. These fires release primarily carbon dioxide (CO_2), along with methane and nitrogen oxides, all of which not only contribute to environmental challenges but are also toxic to human health. But, fires also emit aerosols, soot (extremely fine particles) and tar.

In addition, as they are more numerous and larger, fires increasingly affect the quality of the air breathed by the population. The combustion of trees releases carbon dioxide (CO_2), which is the primary greenhouse gas responsible for global warming.

Figure 6 presents a calculation of the amount of released carbon dioxide (Es) by year, based on burned forest massifs. The calculations were made according to the following [6]:

$$Es = \beta Sx.E_f, \quad (4)$$

where $\beta = 0.9$ is the burning factor, %; S is the burned forest stands in ha; and B is the heat load of forest massifs, kW/m^2. For the calculations, an average value was taken for forest massifs typical for the territory of Bulgaria; $E_f = 0.121$- coefficient of CO_2 release.

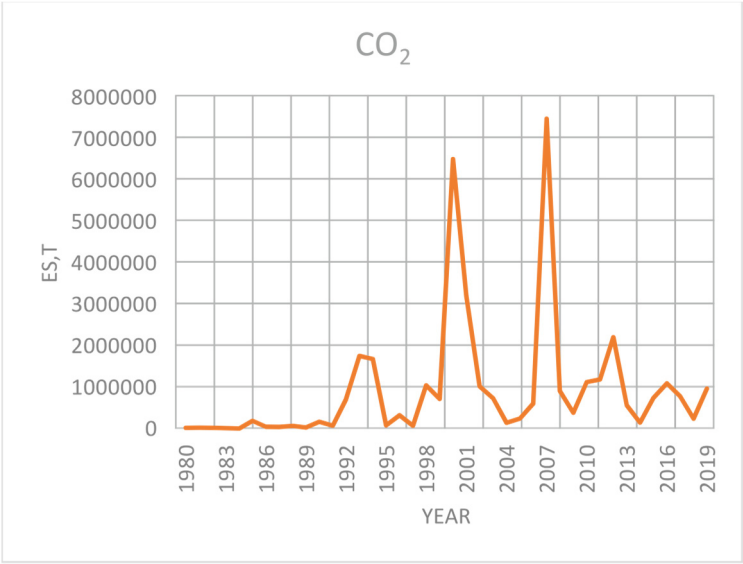

Figure 6. Amount of emitted carbon dioxide for the period 1980–2019.

In Figures 7–10 is the given amount of emitted carbon dioxide for deciduous and coniferous forest for 2021 and 2022 divided by municipality in Bulgaria.

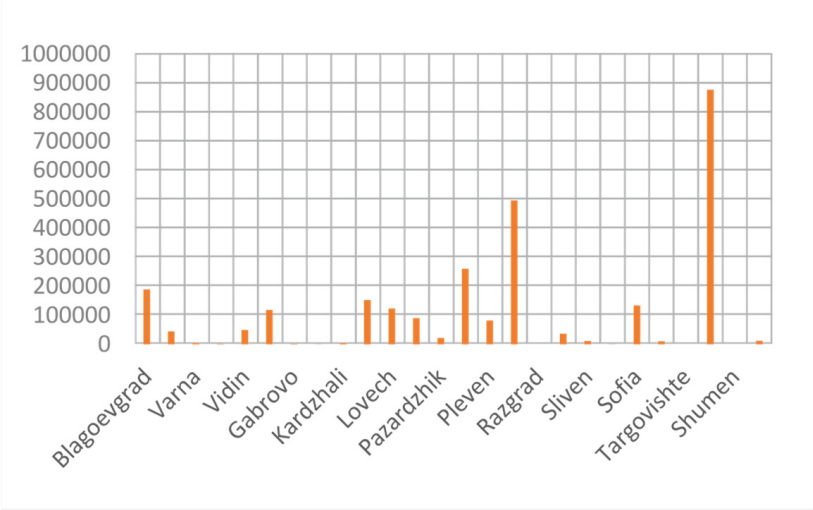

Figure 7. Amount of emitted carbon dioxide in deciduous forests for 2021.

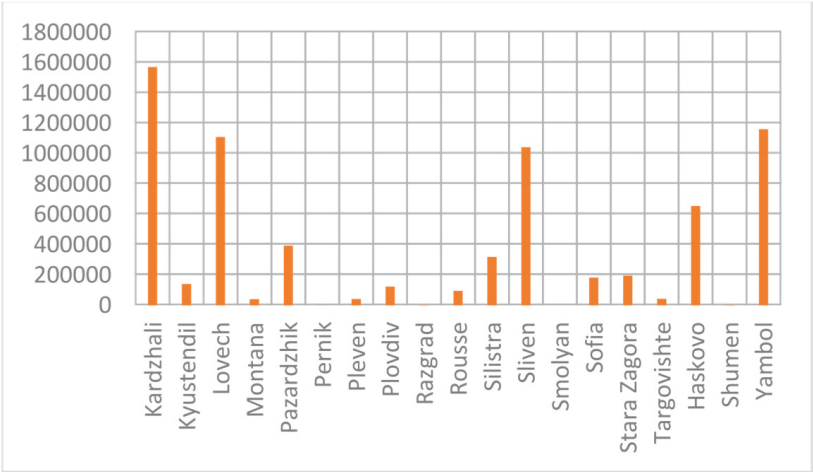

Figure 8. Amount of emitted carbon dioxide in deciduous forests for 2022.

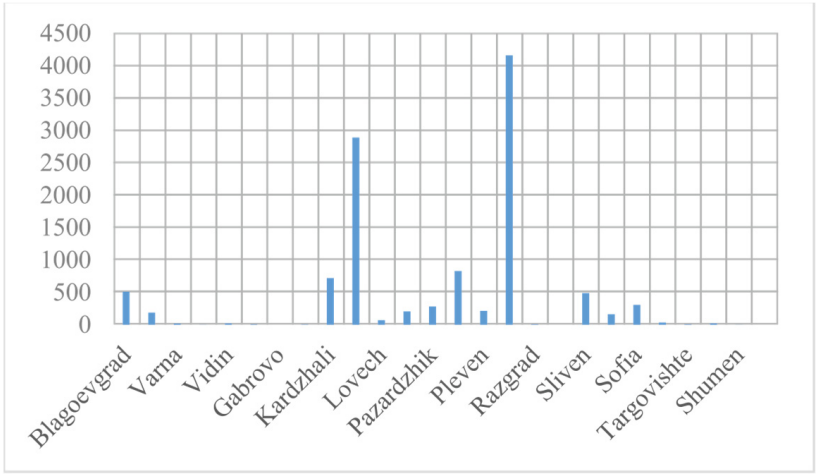

Figure 9. Amount of emitted carbon dioxide in coniferous forests for 2021.

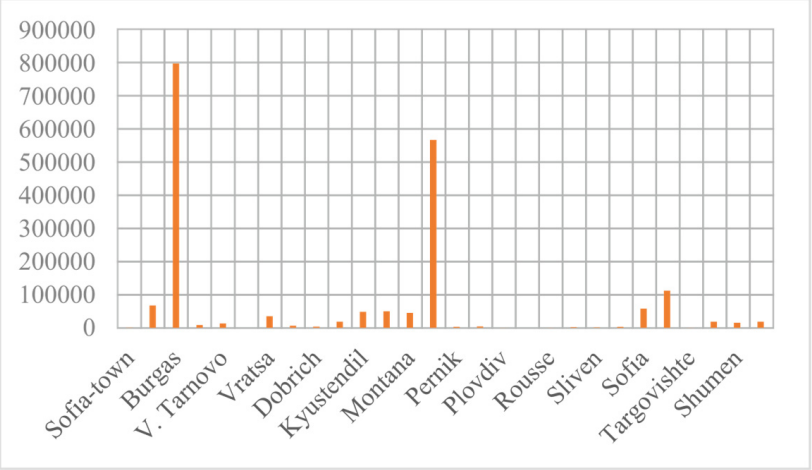

Figure 10. Amount of emitted carbon dioxide in coniferous forests for 2022.

The results are made according (3) for deciduous and coniferous forests.

The heat load is taken as an arithmetic mean of the most common trees in broad-leaved and coniferous forests in the territory of Bulgaria. The value of B for different kinds of trees is given in Table 1.

Table 1. Trees B (heat load) value.

Kind of Tree	B, kW/m^2
Alder	1417
Clear	1945
Apple	2184
Beech	2224
Birch	1484
Cherry	1452
Chestnut	1457
Elm	1419
Oak	2354
Juniper	1473
Spruce	1255
Sycamore	1579
Walnut	1797
Willow	1425
Pine	1287
Fir	1182
Maple	2045

Nearly 70% of Bulgaria's forests are deciduous. They are widespread in the lowlands, plains, and low mountains, even at an altitude of up to 1500 m above sea level.

The most widespread broad-leaved tree species are oaks, beech and hornbeam. Apart from them, sycamores and ash, elm, linden, and poplar, etc., are often found in our forests.

The most characteristic conifers of Bulgaria are the white pine, the black pine, the spruce, the fir, the white and the black mulberry, and the squat, etc. White pine is the most widespread coniferous tree species in Bulgaria, followed by spruce. Forests with a predominant presence of black pine are ranked third in terms of area, and forests with the presence of common fir are also relatively widespread.

4. Conclusions

The effects of fires on the environment and on humans are attracting increasing attention for their frequency and prevalence. Fires are a source of carbon gases, dust particles and volatile organic compounds, thereby affecting air quality and the chemical

composition of the atmosphere. The effects of large fires can be traced over thousands of kilometers and even over other continents. In the area affected by the fires, the quality of water resources deteriorates, and conditions are created for erosion and increased surface runoff. After the fire, the affected ecosystems are greatly altered, with biodiversity threatened when native species lose their ability to recover. In this work, an analysis of the degree of risk by area in Bulgaria is made, and the amount of carbon dioxide released into the environment as a result of forest fires is shown. The analysis is made for the period of 1980 to 2018. The results for burning forests from different types of trees and the calculated amount of CO_2 released into the atmosphere due to forest fires are given.

Author Contributions: Conceptualization, R.V. and E.G.; methodology, I.S.; software, E.G.; validation, R.V., writing—original draft preparation, R.V.; writing—review and editing, I.S.; visualization, E.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Technical University of Sofia.

Informed Consent Statement: Not applicable.

Acknowledgments: This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № ДО-230/06-12-2018).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Halofsky, J.E.; Peterson, D.L.; Harvey, B.J. Changing wildfire, changing forests: The effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. *Fire Ecol.* **2020**, *16*, 4. [CrossRef]
2. Sturrock, R.N.; Frankel, S.J.; Brown, A.V.; Hennon, P.E.; Kliejunas, J.T.; Lewis, K.J.; Worrall, J.J.; Woods, A.J. Climate change and forest diseases. *Plant Pathol.* **2011**, *60*, 133–149. [CrossRef]
3. Carlini, E.M.; Michi, L.; Minto, L.; Chiereghin, F.; Genovese, C.; Foppa, R.; Fedrizzi, A. Forest fire or other dangerous situations: Safety procedure for overhead lines. In Proceedings of the AEIT International Annual Conference (AEIT), Florence, Italy, 18–20 September 2019; pp. 1–6. [CrossRef]
4. Seidl, R.; Thom, D.; Kautz, M.; Martin-Benito, D.; Peltoniemi, M.; Vacchiano, G.; Wild, J.; Ascoli, D.; Petr, M.; Honkaniemi, J.; et al. Forest disturbances under climate change. *Nat. Clim. Chang.* **2017**, *7*, 395–402. [CrossRef] [PubMed]
5. Johnson, B.R.; Ager, A.A.; Evers, C.R.; Hulse, D.W.; Nielsen-Pincus, M.; Sheehan, T.J.; Bolte, J.P. Exploring and Testing Wildfire Risk Decision-Making in the Face of Deep Uncertainty. *Fire* **2023**, *6*, 276. [CrossRef]
6. Guo, M.; Li, J.; Wen, L.; Huang, S. Estimation of CO_2 Emissions from Wildfires Using OCO-2 Data. *Atmosphere* **2019**, *10*, 581. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.