Journal of Environmental Protection, 2018, 9, 461-467
http://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

A Critical Examination of the Relationship between Wildfires and Climate Change with Consideration of the Human Impact

Nadin Boegelsack[1], Jonathan Withey[2], Gwen O'Sullivan[2], Dena McMartin[1]

[1]Faculty of Engineering and Applied Sciences, University of Regina, Regina, SK, Canada
[2]Faculty of Science and Technology, Mount Royal University, Calgary, AB, Canada
Email: nboegelsack@mtroyal.ca

How to cite this paper: Boegelsack, N., Withey, J., O'Sullivan, G. and McMartin, D. (2018) A Critical Examination of the Relationship between Wildfires and Climate Change with Consideration of the Human Impact. *Journal of Environmental Protection*, **9**, 461-467.
https://doi.org/10.4236/jep.2018.95028

Received: March 23, 2018
Accepted: May 5, 2018
Published: May 8, 2018

Abstract

The relationship between climate change and wildfires was examined to summarize factors associated with vulnerability to wildfires. The complex and cyclic nature of interaction effects between the two was highlighted and the following conclusions were drawn. Climate change is leading to more frequent wildfires with higher intensity, resulting in release of more gasses and particulate matter that further exacerbates the progression of climate change. Direct and indirect impacts are detailed in the main body. A new fire management policy is deemed necessary, with a more local approach being recommended. Human impacts were found to further complicate the already complex relationship. It is recommended to treat accidental and incendiary fires separately for the purpose of evaluating fire management regimes. This requires successful advances in current fire investigation techniques.

Keywords

Wildfire, Carbon Emission, Climate Change, Fire Management

1. Introduction

Wildfires are a global phenomenon, occurring on a regular basis in Australia, Greece, Spain, USA, and Canada, amongst other countries [1] [2]. While they are often referred to in a negative context, they have fulfilled an ecological need for millennia. The regular burning of forests provides a natural fuel reduction, as well as disperses the fuel continuity. This, in turn, greatly improves the resistance to fires and disease or pest outbreaks by favoring more fire-resistant tree species and spacing the trees further apart to avoid an easy spread [3] [4]. Many animal and plant species, such as Koalas in Australia or Woodland Caribou in Canada, have relied on wildfires as a naturally occurring forest regulation scheme [5] [6]. Despite this interdependency, the destruction caused by wildfires also affects the lives and habitats of both animals and humans alike [1] [4].

Available fuels, current weather conditions, ignition agents, and human activity are the main factors influencing wildfire occurrence; fuel type and fuel amount (needed for ignition), fuel continuity and fuel structure (needed for fire spread), fuel moisture and fuel amount (which determine the area burnt), all affect the frequency and behavior of wildfire. The structure is generally classed as ground fuel, surface fuel, ladder fuel, and crown fuel, not all of which are required for a fire to spread, but which all impact the spread differently [3]. The main weather variables impacting fire behavior are air temperature, relative humidity, wind direction, and wind velocity [3] [7]. The variety of data models available suggests broad agreement regarding the connection between climate change and wildfire occurrence. However, the outcome and extent of this connection are found to vary considerably between each model. Nonetheless, the following broad trends have been observed over the past several decades, and are predicted to continue: average temperatures are rising, and water supplies are meeting their limitations quicker, resulting in more frequent and longer lasting droughts across all climate zones; forest management is becoming progressively more challenging with threats to biodiversity due to increasing selectivity in tree species, insects, pests and diseases expanding their territories, as well as woodland caribou and other animal or plant species losing their mature and old growth habitats; and, the regeneration capacity of certain woodlands is stretched to its limits, leading to a critical ecosystem change from woodlands to prairies [1] [4] [6] [7] [8] [9].

This article seeks to point out the various factors, and to an extent their impact, on the relationship between wildfires and climate change in order to provide a summary of risk factors associated with vulnerability to wildfires and their global implications.

2. Climate Change Effect on Wildfires

2.1. Direct Effects

Rising temperatures are increasing heat stress on trees by increasing evaporation and lowering the average humidity. The resulting prolonged drought periods and significantly longer fire seasons, provide superior conditions for ignition, thereby increasing the number of critical fire weather days. Conditions for these days include strong and shifting winds, low humidity, high temperatures, as well as the chance for dry lightning [1] [9]. As shown in [9], the largest fires normally start on critical fire weather days. An effective summary is provided in [7] when concluding that the rate of occurrence and wildfire spread is a function of the environment, it being influenced by change in climate, and the components in a chemical reaction, which are also influenced by a change in climate. Thus, combustion is much more likely to occur when fuel moisture is low, and low fuel moisture is one of the main impacts of a warmer climate on trees. However, it is important to note that fuel moisture also serves to provide a prime example of the complexity involved in discussing the relationship between climate change and wildfires. While it is true that drier fuels provide better materials for ignition, climate change also leads to increased precipitation in some areas, which can serve to counteract the effect of increased evaporation [9]. While the change in timing of precipitation is well documented, it remains one of the most overlooked, albeit crucial, factors when analyzing wildfire ignition in the context of climate [1]. The biggest natural source for ignition for wildfires is lightning [10] and a warming climate is favoring an increase in frequency for lightning and lightning storms [1]. This is further fuelled by the persistence of so-called "blocking ridges" in the upper atmosphere, which intensify drier and warmer weather conditions by preventing precipitation [1] [9]. As such, it is no surprise that the expected effect of climate change on wildfires is an increase in frequency, intensity, and severity of wildfires, with larger burn areas and longer fire seasons [1] [4] [6] [9].

2.2. Indirect Effects

The indirect effects of climate change on wildfire occurrence and behavior are mainly related to impacts on tree health and distribution. For example, increased pollution has been linked to tree health and mortality, which in turn alters the fuel potential of trees. [6] Climate change is likely to continue affecting stand compositions, tree growth, and age distribution, as well as stand structure, litterfall, and decomposition rates. Since these factors directly affect the fuel load potential, they have potential to directly impact wildfires. Additionally, wildfires have been shown to directly impact the fuel moisture in trees, although long-term moisture content was linked to canopy attributes [11]. Both the frequency of wildfires, and canopy properties, are affected by climate change as demonstrated above.

The most significant indirect effect manifests in pest populations. Pine beetles, for instance, can dramatically influence wildfires. While human activity plays a significant role (see 4.), climate change has created ideal conditions for bark beetles to be hosted in trees and to expand their manifestation into larger territories in an unprecedented manner [3] [7]. One of these [3] have also shown that certain tree species produce large quantities of terpenoids upon a perceived beetle infestation. Terpenoids are highly flammable compounds which dramatically alter fire behavior. As others [12] demonstrated, pine trees are surprisingly good ladder fuel, despite having much higher fuel moisture content. This was hypothesized to be due to their high terpene content, making them an ideal tree species to spread fire, with re-ignition possible at a later stage.

Despite the apparent simplicity in these established relationships, they mask a complex system of interactions. For instance, a temporary increase in precipitation reduces the fire risk by increasing fuel moisture. This in turn may lead to accrued biomass and potential beetle infestation, which can increase terpene contents. The next fire during a drier period will therefore ignite more easily, spread more rapidly, and burn with higher intensity. With more frequent, large, high severity fires impacting systems with potentially unknown factors, fire intensity and behavior is becoming more and more difficult to predict [1] [3] [4]. This exacerbates the risk for firefighters, who rely on the anticipation of wildfire behavior, and points to the need for new fire management strategies.

3. Wildfire Effect on Climate Change

Wildfires are a significant source of greenhouse gas emissions, which have been linked to climate change. An immediate release of carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO) from combustion is followed by a release of black carbon and other particulate matter in smoke. Longer-term slow CO_2 release has also been noted from increased decomposition of organic matter and lower uptake via photosynthesis from the recovering and new vegetation. CO_2 and black carbon are currently ranked as the two largest atmospheric warming contributors, leading to a cyclic effect between climate change and wildfire frequency [1] [4]. The observed arctic warming is presumed to be linked to atmospheric warming in combination with soot deposited on ice and snow, which results in further solar adsorption and increased melting. Subsequent permafrost degradation increases the probability of fires in Canadian areas such as peatlands. Allowing fires to burn more deeply into exposed organic material increases the occurrence of holdover fires, and contributes further to the arctic ice retreat. In addition, the release of stored carbon further exacerbates carbon emissions [1] [9] [13]. Although organic-rich soils, such as peat, require high heat to self-sustain a smoldering combustion, they have a long burning time, very high carbon emission, and are more persistent in comparison to other fires [14]. This is not a localized problem, as black carbon particulates have been shown to have a significant transport range [1] [13]. Previous research [13] demonstrated particles to have travelled over a minimum of six days, while retaining an almost unchanged composition. Particle transmission with circular wind patterns, such as El Niño, can further extend travel, depositing more soot on arctic ice and snow, and increasing the effect of wildfires on atmospheric warming further [1].

It is clear that the relationship between wildfires and climate change is a complex and circular one, where climate change increases the frequency of wildfires, and wildfire emissions increase the rate of climate change.

4. Human Impact

The detrimental health effects of wildfires, especially by virtue of the effect on the human respiratory system, are well-known and well-documented. It is even hypothesized that wildfire-specific particulate matter has a stronger effect than other sources due to its composition [4] [14] [15]. Given the wealth of literature, this paper focuses instead on the effect of human activity on wildfires in the context of climate change.

4.1. Direct Impact

Since humans are the largest non-natural source of wildfire ignition, human activity always alters the observed ignition patterns [1] [5] [16]. The precise impacts of human activity are difficult to estimate, as they include intentional fires escaping set boundaries, accidental fires due to ignorance of ignition factors, as well as arson [1]. Not only does this impede evaluation of the effectiveness of fire management strategies, it also places more strain on arson investigation techniques. Previous work [16] indicates that the current ASTM standards in place have never been validated, and therefore question their performance. Shortcomings of regarding current arson investigation materials and methods have been noted in the literature [17] [18] [19] [20], but are yet to be addressed with a feasible solution.

4.2. Indirect Impact

Indirect human impact can be seen in a variety of forms: fire suppression measures, extensive logging and grazing influencing the stand compositions and structures, biomass burning for clearing, the introduction of invasive species (especially pests), fuel build-up from land abandonment, etc. [1] [3] [4]. In particular, fire management techniques, such as prescribed fires and mechanical treatment, have changed fuel type and continuity factors when analyzing wildfire potential. Although these techniques have met with success on a small scale, they are not financially feasible on a large scale. Additionally, mechanical measures implemented on a large scale may contribute to a further shift in ecosystems that are already at a tipping point due to climate change [3] [4] [5]. Complications from past management practices have recently been noted as increasingly complex burn patterns emerge, combined with higher intensity fires due to fuel buildup from successful fire management. These complications pose an immediate danger to fire fighters and civilian residents, who rely on the correct anticipation of fire behaviour for safe and necessary evacuations, amongst other things [3] [4]. One group of researchers [21] demonstrated that the impact on soil composition between prescribed fires and wildfires were very similar with the only difference being in longevity of the change as wildfires burn with higher intensity. The strain on the soil, however, may indicate that continuous, prescribed fires are not sustainable. Conversely,another research team [22] showed a distinct difference in soil microbial response to fire between pasture and naturally fire-adapted woodland, suggesting use of the microbial composition as a future way of assessing fire adaptability, and as part of a local-level fire management plan.

While new fire management strategies are clearly needed, they are difficult to implement as priorities often shift on short notice, making longer-term planning and objectives unattainable, especially at a global level [23] [24]. Additionally, any change in the fire management regime directly impacts the long-term carbon storage in forests, and as such must be well thought-out prior to implementation [1].

5. Conclusion

The relationship between climate change and wildfires is a two-way interaction with many complex factors involved. As a general summary, it can be concluded that climate change leads to more frequent and more severe wildfires, which in turn emit more gasses and particulate matter to increase atmospheric warming. It is evident that a new fire management approach is needed. Based on the findings, a local approach is recommended as the effect of climate change can vary greatly between different areas. In addition, human activity is considered a major contributor to the already complicated relationship between wildfires and climate change. To evaluate the effectiveness of new management techniques, it is deemed appropriate to treat incendiary ignitions separately from accidental ignitions. This, however, requires further advances in current forensic techniques.

References

[1] AAAS (2017) Forensic Science Assessments: A Quality and Gap Analysis—Fire Investigation, American Association for the Advancement of Science Report Prepared by Almirall, J. *et al.*

[2] Wildfire, A. (2017) wildfire.alberta.ca/resources/default.aspx, website.

[3] Allen, C.D., *et al.* (2010) A Global Overview of Drought and Heat-Induced Tree Mortality Reveals Emerging Climate Change Risks for Forests. *Forest Ecology and Management*, **259**, 660-684. https://doi.org/10.1016/j.foreco.2009.09.001

[4] Baerncopf, J. and Hutchins, K. (2014) A Review of Modern Challenges in Fire Debris Analysis. *Forensic Science International*, **244**, e12-e20. https://doi.org/10.1016/j.forsciint.2014.08.006

[5] Bentley, P.D. and Penman, T.D. (2017) Is There an Inherent Conflict in Managing Fire for People and Conservation? *International Journal of Wildland Fire*, **26**, 455-468. https://doi.org/10.1071/WF16150

[6] Blauw, L.G., *et al.* (2017) Tree Species Identity in High-Altitude Forests Determines Fire Spread through Fuel Ladders from Branches to Soil and *Vice Versa*. *Forest Ecology and Management*, **400**, 475-484. https://doi.org/10.1016/j.foreco.2017.06.023

[7] Cawson, J.G., *et al.* (2017) Fuel Moisture in Mountain Ash Forests with Contrasting Fire Histories. *Forest Ecology and Management*, **400**, 568-577. https://doi.org/10.1016/j.foreco.2017.06.046

[8] De Haan, J.D. and Icove, D.J. (2012) Kirk's Fire Investigation. 7th Edition, Pearson Publishing, Upper Saddle River, NJ.

[9] Flannigan, M.D., *et al.* (2009) Implications of Changing Climate for Global Wildland Fire. *International Journal of Wildland Fire*, **18**, 483-507. https://doi.org/10.1071/WF08187

[10] Fultz, L.M., *et al.* (2016) Forest Wildfire and Grassland Prescribed Fire Effects on Soil Biogeochemical Processes and Microbial Communities: Two Case Studies in the Semi-Arid Southwest. *Applied Soil Ecology*, **99**, 118-128. https://doi.org/10.1016/j.apsoil.2015.10.023

[11] Gauthier, S., *et al.* (2014) Climate Change Vulnerability and Adaptation in the Managed Canadian Boreal Forest. *Environmental Review*, **22**, 256-285. https://doi.org/10.1139/er-2013-0064

[12] Global Fire Monitoring Centre (GFMC) (2017). http://www.fire.uni-freiburg.de/current/globalfire.htm

[13] Guyette, R.P., *et al.* (2014) Future Fire Probability Modelling with Climate Change Data and Physical Chemistry. *Forensic Sciences*, **60**, 862-870.

[14] Jenkins, M.J., *et al.* (2014) Interactions among the Mountain Pine Beetle, Fires and Fuels. *Forensic Sciences*, **60**, 489-501. https://doi.org/10.5849/forsci.13-017

[15] Li, Y.Y., Liang, D. and Shen, H. (2013) An Analysis of Background Interference on Fire Debris. *Procedia Engineering*, **52**, 664-670. https://doi.org/10.1016/j.proeng.2013.02.203

[16] Liu, J.C., *et al.* (2016) Particulate Air Pollution from Wildfires in the Western US under Climate Change. *Climate Change*, **138**, 655-666. https://doi.org/10.1007/s10584-016-1762-6

[17] Liu, J.C., *et al.* (2017) Wildfire-Specific Fine Particulate Matter and Risk of Hospital Admissions in Urban and Rural Counties. *Epidemiology*, **28**, 77-85. https://doi.org/10.1097/EDE.0000000000000556

[18] Martin-Alberca, C., Ortega-Ojeda, F.E. and Garcia-Ruiz, C. (2016) 9 Analytical Tools for the Analysis of Fire Debris. A Review: 2008-2015. *Analytica Chimica Acta*, **928**, 1-19. https://doi.org/10.1016/j.aca.2016.04.056

[19] Moroni, B., *et al.* (2017) Morphochemical Characteristics and Mixing State of Long Range Transported Wildfire Particles at Ny-Alesund (Svalbard Islands). *Atmospheric Environment*, **156**, 135-145. https://doi.org/10.1016/j.atmosenv.2017.02.037

[20] Prendergast-Miller, M.T., *et al.* (2017) Wildfire Impact: Natural Experiment Reveals Different Short-Term Changes in Soil Microbial Communities. *Soil Biology & Biochemistry*, **109**, 1-13. https://doi.org/10.1016/j.soilbio.2017.01.027

[21] Price, D.T., *et al.* (2013) Anticipating the Consequences of Climate Change for Canada's Boreal Forest Ecosystems. *Environmental Review*, **21**, 322-365. https://doi.org/10.1139/er-2013-0042

[22] Sanseverino-Godfrin, V., Garbolino, E. and Hinojos-Mendoza, G. (2016) Evolution of the Legal Prevention Measures Concerning Forest Fire Risk in a Context of Climate Change. *Safety Science*, **97**, 73-80. https://doi.org/10.1016/j.ssci.2016.06.003

[23] Schoennagel, T., *et al.* (2017) Adapt to More Wildfire in Western North American Forests as Climate Changes. *Proceedings of the National Academy of Sciences of the United States of America*, **114**, 4582-4590. https://doi.org/10.1073/pnas.1617464114

[24] Turner, D.A., *et al.* (2015) Microbial Degradation of Gasoline in Soil: Effect of Season of Sampling. *Forensic Science International*, **251**, 69-76. https://doi.org/10.1016/j.forsciint.2015.03.013