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Reply on RC1

Liliana Perez

Community comment on "ABWiSE v1.0: toward an agent-based approach to simulating wildfire spread" by Jeffrey Katan and Liliana Perez, Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-179-CC1, 2021

This article presents a Agent Based Model for wildfire spread. The article is clearly written, and its importance is highlighted by the growing number of wildfires each year. Under these circumstances, we need more models like this. Hopefully, the authors will make their code available such that it can be used as a base for further improvement by the community. The experimental set-up and validation are clearly explicated, and diagrams are clear. Below are a set of points that can be addressed in a revision:

We are very grateful to the referee for their invaluable feedback. We strive to address the referee's comments below. In our response, the original comments are in italics, and our responses follow.

- *The introduction needs acknowledgement of anthropogenic forest fires. This needs to cover the fact that controlled burning has been used for a long time (and effectively) as a forest management tool and the intensification of forest fires due to climate change which is also anthropogenic.*

The authors would like the reviewer for this comment and agree that this information needs to be included in the Introduction. Following is the proposed addition:

"Fire is an integral part of ecosystems the world over, but also poses a serious danger to human life and property (Brenkert-Smith, Dickinson, Champ, & Flores, 2013; Butry, Mercer, Prestemon, Pye, & Holmes, 2001; Carroll, Higgins, Cohn, & Burchfield, 2006; Chuvieco, Martínez, Román, Hantson, & Pettinari, 2014; Kochi, Donovan, Champ, & Loomis, 2010; Richardson, Champ, & Loomis, 2012). In recent years, anthropogenic climate change has exacerbated this danger chiefly by lengthening growing seasons, and increasing the risk of drought (Flannigan et al., 2016; Lozano et al., 2017), leading to more frequent and more extreme fires in many parts of the world (Chuvieco et al., 2016; M. C. Kirchmeier-Young, Gillett, Zwiers, Cannon, & Anslow, 2019; Megan C. Kirchmeier-Young, Zwiers, Gillett, & Cannon, 2017). The use of controlled burning has, for a very long time (Gott, 2005; Roos et al., 2021), helped to mitigate the risks of extreme fires and to maintain forest health (Boer, Sadler, Wittkuhn, McCaw, & Grierson, 2009; Camp & Krawchuk, 2017; Paulo M Fernandes & Hermínio S Botelho, 2003). Given the exacerbation of conditions ripe for extreme fires, it is paramount to predict how a fire might spread if it starts, especially for prescribed burns. Fire behaviour models…"

- *Good summary of fire models. However, the jump to the models is a bit abrupt. A* *mention of satellite-based forest fire monitoring approaches would help. Here is a great example using MODIS: https://modis-fire.umd.edu/*

The authors welcome this excellent suggestion and propose to add a paragraph to integrate this information. In addition to providing a smoother transition, the implementation pf this suggestion supports our brief discussion of the value of remotely sensed fire observation data for model validation, starting on line 377.

Proposed text:

"**1.1 Fire behaviour models**

Bearing in mind that wildfires are a global phenomenon that pose significant and growing threats to human lives, property, wildlife habitat, regional economies and global climate change, a variety of tools to tackle and envisage fire propagation have been developed. Some of these tools have the purpose of monitoring (Chu & Guo, 2013; Chuvieco et al., 2019; Giglio, Descloitres, Justice, & Kaufman, 2003; Giglio, Schroeder, & Justice, 2016), others to forecast the likelihood of wildfire events (Cheng & Wang, 2008; Taylor, Woolford, Dean, & Martell, 2013; Yue et al., 2018), and lastly some to model and simulate fire behaviour (Sullivan, 2009a, 2009b, 2009c). The literature concerning this latter category is of particular interest to the goal of this study."

- *"Ultimately, the goal of such a fire simulation model is to predict fire behavior, but presently, the purpose 150 of ABWiSE is to explore how ABM, using simple interactions between agents and a simple atmospheric feedback model, can simulate emerging fire spread patterns." – This needs further explanation. How is predicting fire behavior different from simulating emerging fire spread? What is ABWiSe achieving and what is it leaving out. What are the merits and demerits of the trade-off?*

The purpose of the statement quoted above was to indicate that ABWiSE is currently a proof of concept, and should not be used for fire behaviour prediction where the results may impact decision-making. In the revised manuscript, we will change the phrase to:

"Ultimately, the goal of such a fire simulation model is to provide predictions of the behaviour of hypothetical fires. Presently, this paper uses ABWiSE to explore how ABM, using simple interactions between agents and a simple atmospheric feedback model, can simulate emerging fire spread patterns."

Perhaps a point of confusion is the use of the term "emerging", which we use in reference to the emergent properties of a complex system, rather than "a prediction of what unfolds". Ultimately, there is no trade-off between the goal of simulation and the goal of prediction, because if we can simulate well, we can predict well. The caveat, and the reason we focus on demonstrating the value of ABM for simulating forest fires, is that by eschewing physical simulation in favour of empirical calibration, we gain rapid computation but cannot confidently extrapolate our model to new scenarios without further validation. So, yes, we can predict fire behaviour through simulation for the fires ABWiSE is calibrated to, but cannot yet ascertain the validity of predictions for other fires.

- *Line 185: FWI seems to provide a great resource to test model assumption regarding wind speed. If it is not too complex to incorporate within the current study, this will be a good addition to the paper. Also, is the relationship between RoS and wind speed mentioned in line 205 the same as used in FWI?*

The FWI provides an index of fire danger based on fuel moisture, temperature, and wind, but not fuel type. Rate of spread estimates are provided by the Fire Behaviour Prediction (FBP) system that uses the FWI equations for some inputs. This system has been in use for decades, but does not account for any form of feedback mechanism. The way ABWiSE uses feedback loops to replicate fire behaviour means it is difficult to isolate one particular assumption at a time. In particular, ABWiSE's variables for fuel availability and flammability are similar to the Buildup Index and the Fine Fuel Moisture Code components of the FWI, respectively; however, for the latter pair, the FFMC takes wind speed as an input, as it forms a component of the Initial Spread Index (another component of the FWI), while flammability in ABWiSE does not. Thus, using the FWI to supply fuel availability and flammability values for ABWiSE would have required a reworking of the FWI without wind.

While it would be a great idea to take the FBP system apart and recombine it for use in a complex ABM where feedback plays a major role, we deemed it beyond the scope of this study. The revised manuscript will contain an explanation to this effect in the paragraph containing line 185.

As for testing model assumptions regarding wind speed against the FWI, in essence, wind speed assumptions are tested in whole with the perimeter comparison methods. Prometheus uses the FBP and FWI to calculate the RoS for its fire perimeter, and we calibrated ABWiSE against two base cases generated by Prometheus. We considered performing perimeter comparisons between Prometheus' simulations of the Dogrib fire, but chose not to, since the goal is to simulate a real fire as well as possible, not simulate a simulation as well as possible.

The relationship between RoS and wind speed is not the same as used in the FWI, though it makes use of the same form of equation. However, the various feedbacks change the final RoS from that particular equation, so it would be moot to use the exact same relationship between wind speed and RoS as the FWI. We will clarify this in the revised manuscript.

- *How does ABWiSE improve upon Prometheus?*

In short, by incorporating feedback mechanisms while using similar inputs appropriate for a Canadian context. However, we make it clear that ABWiSE is no replacement for Prometheus, but rather a step in a new direction that may lead to models that could improve upon Prometheus in many ways.

6. Can the model be used to simulate fire fighting efforts? For example, given that forest fires can span thousands of acres, what happens when fore fighting efforts are concentrated in some area as opposed to another?

Simulating firefighting efforts is absolutely possible by coupling ABWiSE with a model that could determine *where* firefighting efforts would occur. One possible way to incorporate fire-fighting would be to simply reduce the flammability and fuel availability values in those cells being suppressed. This is an interesting topic and we may add it to our discussion of future work.

- *Figure 3: Great map. Would it be possible to use a different color scheme to better delineate the different vegetation types?*

We would like to thank the reviewer, and in order to ask to his request we have created two alternative maps. Please see the supplementary material for two new colour options.

8. The 4 cases can be presented in a table to improve readability. I kept having to find them in the text to remind me exactly what they were.

The authors would like to thank the reviewer for his suggestions and will gladly do so.

Lastly, the referee suggests we make our code and data available for use and improvement by the broader research community. We have made it available as a GitHub repository, and included the information to access it in the *Code and data availability* section of the manuscript, on line 427.

Figure 3 alternative color schemes:

Option 1) colours based on FBP system colour scheme (see PDF attached)

Option 2) Technically coherent colour palette (see PDF attached)

Please also note the supplement to this comment:
https://nhess.copernicus.org/preprints/nhess-2021-179/nhess-2021-179-CC1-supplement.pdf