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Natural Hazards and Earth System Sciences
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Discussions



# *Interactive comment on* "Fine scale assessment of cross boundary wildfire events in the Western US" *by* Palaiologos Palaiologou et al.

**Palaiologos Palaiologou et al.**

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This work extends previous fire transmission works to a larger spatial scale, using methods developed by some of the same authors.

The paper is well written, and most of it is very clear. The design of the research is well done, the methods are suited for the purpose, and the major findings are well supported by the results and other studies referenced by the authors.

Reply: Many thanks for the comments. We have revised the manuscript carefully to address all your comments/suggestions. Please check the file named "NHESS_ALL_LANDS_Revised_track_changes.pdf" to see the edits with track changes, and the "NHESS_ALL_LANDS_Revised_no_track.docx" to see the clean version of the manuscript.

General comments:

1. I understand that the same simulation methods described here have been used in other works and you want to avoid unnecessary repetitions. Nevertheless, as you mentioned, the spatial scale of the simulations presented in this work is unprecedented, and researchers working on similar topics\tools will surely want to understand how they were done. For example: what was the total number of simulations, and what was the spatial resolution of the data used? Adding to this comment, I think it is important to mention that multiple fire seasons are simulated (and not only individual wildfires).

Reply: The FSim simulation section has been substantially edited and expanded, considering the reviewer's suggestions.

2. At the end of the Introduction you depict three very clear specific questions that you want to address in this work. Then you add that "the results were used to understand how anthropogenic actions influence (...) fire transmission, notably parcel geometry, landownership composition and landscape fragmentation (. . .)." Where is this shown in the results? For example, the analysis of "checkerboard vs. large boundary lines between two land tenures". Additionally, in what sense is "parcel geometry" a "anthropogenic action"? Regardless, if this analysis is\was really performed my suggestion is that you add it to a 4th question.

Reply: We followed the reviewer's suggestion and added this part as a 4th question. Previous research efforts revealed that parcel geometry and relative size of different ownerships set the stage for fire transmission across boundaries (Ager et al., 2014, 2017, 2018) and is defined by anthropogenic actions. Landscape is full of artificial boundaries, and human actions define not only ownership boundaries and shape, but also what management and land use is occurring in each parcel. At the scale of public land parcels in the United States, transboundary fire risk is primarily an artifact of landscape fragmentation with respect to ownership and administrative fire management jurisdictional boundaries (Ager et al., 2017). In terms of the 'firescape", inside ownership parcels new boundaries are created especially by vegetation management practices (half parcel was treated/half not) or other activities (half grazed/half not). The most prominent results are in Figure 6, where we show how the percentage of incoming fire is reduced with increasing parcel size across all land tenures. In Figure 2 we show how landownership composition defines the amounts of incoming, self-burning and outgoing fire. In Figure 5 we demonstrate the effect of checkerboard vs. large boundary lines between two land tenures on fire transmission. For example, the large red area in southeastern part of Arizona inside the Apache-Sitgreaves National Forest share a large common boundary with Tribal lands (purple) covered with grass and shrub fuel models (please see example figure 1). North of this area, the checkerboard effect between private and state lands create the high incoming fire on private lands (orange, Figure 5).

Example figure 1: Land tenures in Arizona (first figure after the comments)

References:

Ager, A.A., Day, M.A., Finney, M.A., Vance-Borland, K., and Vaillant, N.M. 2014. Analyzing the transmission of wildfire exposure on a fire-prone landscape in Oregon, USA, Forest Ecology and Management, 334, 377-390.

Ager, A.A., Evers, C.R., Day, M.A., Preisler, H.K., Barros, A.M., & Nielsen-Pincus, M. 2017. Network analysis of wildfire transmission and implications for risk governance. PloS one, 12(3), e0172867.

Ager, A.A., Palaiologou, P., Evers, C.R., Day, M.A., and Barros, A.M.G. 2018. Assessing transboundary wildfire exposure in the southwestern United States, Risk Analysis, 38, 2105-2127.

3. The statistical model of human\natural ignitions needs to be clarified. This is an important part of your work because part of your results (and conclusions) depend

on the predicted cause of ignitions. How well does this model work? Did you calculate performance statistics? Did you use a set to calibrate the model and another to validate? A complex model is not synonymous of a good model. Please provide a clear(er) equation of the model so that all interested readers can understand and replicate if necessary.

Reply: We substantially revised the section and we added a new figure in the appendix (reliability diagram). A clearer equation has been added. We also explain how the goodness of fit of the model was assessed.

4. What is the difference between a "fireshed" and "community fireshed"? Did you use both?

Reply: Technically, it can be show different values when we examine each community separately vs. all communities. This means that the fireshed as a whole include all lands that expose all communities, with structure exposure values for the entire analysis domain, while a single community fireshed values of structure exposure for that particular community. But this is not the case in our paper. We standardized our terminology and we refer to it as "fireshed", removing the word "community" for the three cases found in the manuscript.

5. Using simulations is an interesting and powerful approach for issues such as the ones studied in this work. However, in my opinion, this should be accompanied whenever possible, by an analysis of the observed patterns. In a general sense, this work disregards much of that "connection to reality". For example, a calibration exercise is not even mentioned. Another example: the patterns of fire transmission reported in 3.1 could be accompanied by an historical analysis to understand how well did the model predict historical fire transmission.

Reply: As we mention in the manuscript, the dataset of simulated fires was retrieved by the FireLab of the Rocky Mountain Research Station. Finney et al. 2011 did an extensive and complete accuracy assessment of the modelled fire perimeters we used in this work with historical data for the period 1992-2008. In that study, they used two metrics for comparing the simulations with observations (1) average burn probability for each FPU, and (2) the fire size frequency distributions for each Geographic Area. FSim could generate outputs that corresponded well to the patterns and trends evident from historical fire records. Conditions which contributed to the historic fires (ignition sources, land cover types and fire spread patterns) appear to be generalizable beyond that time period (1992-2008) and specific landscape pattern, proving that dry and windy conditions overwhelm the sensitivity of fire behavior to fine scale departures from model assumptions experienced under moderate conditions. Also, the range of modeled and historical burn probabilities estimated is generally consistent with those from other North American studies (Martell and Sun, 2008; Littell et al. 2009; Parisien and Moritz 2009). The close correspondence between simulated and observed fire size distributions was similar to that reported by Moritz et al. (2005). In our paper, in addition to the comparison of the historic lightning-caused ignitions with simulated ignitions that we provide in the manuscript, using the 24 years of historic data (1992-2015) from the historic ignition database (Short 2017), we found that the historic annual burned area across the western US was 1,268,412 ha yr-1, while the simulated dataset predicted 1,257,182 ha yr -1. Moreover, a per state comparison between historic and predicted annual burned area is provided in a new appendix table. Largest annual differences between historic and predicted annual burned area were found for Oregon (+40,000 ha yr -1), Washington (+29,000 ha yr -1) and Idaho (+16,000 ha yr -1), and Arizona (-23,000 ha yr -1), Wyoming (-20,000 ha yr -1) and New Mexico (-19,000 ha yr -1). Part of the response was incorporated in the revised manuscript. References:

Finney, M.A., McHugh, C.W., Grenfell, I. C., Riley, K.L., and Short, K.C. 2011. A simulation of probabilistic wildfire risk components for the continental United States, Stochastic Environmental Research and Risk Assessment, 25, 973–1000.

Littell J.S., McKenzie D., Peterson D.L., Westerling A.L., 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. Ecol Appl 19(4):1003–1021.

Martell D.L. and Sun H. 2008. The impact of fire suppression, vegetation, and weather on the area burned by lightning-caused forest fires in Ontario. Can J For Res 38:1547–1563.

Moritz M.A., Morais M.E., Summerell L.A., Carlson J.M., Doyle J., 2005. Wildfires, complexity, and highly optimized tolerance. Proc Natl Acad Sci 102(50):17912–17917.

Parisien M.A. and Moritz M.A., 2009. Environmental controls on the distribution of wildfire at multiple spatial scales. Ecol Monogr 79(1):127–154.

6. After reading the 1st paragraph of the Discussion: it would be interesting to look at the results in terms of normalized incidence instead of total area (i.e. burned area / total area of a given type of cover). For example, national forests have highest predicted burned area because there is a large incidence or because they have the highest cover area?

Reply: We added two new columns in table 2 showing the total burned area (incoming + self-burning) for each land tenure and the normalized burned area by land tenure area. FS still ranks first in terms of normalized burned area, but followed by city/county, BLM, Public and Private. We also added a new column in table 3 where we show the normalized outgoing fire per land tenure. We added additional explanation both in results and on the first paragraph of the Discussion.

7. Why do you think small parcels tend to receive higher amounts of incoming fire?

Reply: Previous research have shown that decreasing complexity in parcel geometry (low perimeter to area ratio) was associated with decreasing transmitted fire (see Ager et al., 2014). Consider two adjacent land parcels, A and B, of equal size and shape and conditions with respect to fire spread rate, intensity, ignition probability, suppression capacity, and potential loss (ecological, financial or other), and a random direction of wind. The net expected transmission of risk between the two parcels will be equal, despite ignitions in A burning parcel B and vice versa. Changing any one of the factors listed above creates the potential for unequal risk transmission among the parcels. Some of these factors are natural (e.g., wind direction) while others are ecological (e.g., fire regime), or anthropogenic (e.g., fuel management, urban development, or parcel geometry). The challenge at hand is to determine the magnitude of transmission among land parcels defined by administrative or ownership boundaries and identify the relative importance of the contributing factors. Part of the response was incorporated in the revised manuscript.

Ager, A.A., Day, M.A., Finney, M.A., Vance-Borland, K., and Vaillant, N.M. 2014. Analyzing the transmission of wildfire exposure on a fire-prone landscape in Oregon, USA, Forest Ecology and Management, 334, 377-390.

Specific comments:

P2, L30: the fireshed

Reply: we added “the” as suggested by the reviewer.

P3, Study Area and land tenures: please mention here the size of your study area.

Reply: we added the size of the study area (307 million ha)

P3, L23-26: don’t understand the sentence.

Reply: The information on this sentence was retrieved from: USDA Forest Service: Towards shared stewardship across landscapes: An outcome-based investment strategy, USDA Forest Service, Washington, DCFS-118, 2018. We split the sentence in two parts and rephrased as: “More than 65 million ha are of high or very high fire risk (Dillon et al., 2015) across all land tenures. On high or very high fire risk and low natural mortality National Forest System lands we can potentially treat seven million ha through traditional timber harvest methods and 14 million ha through prescribed fire and/or another fuels treatment (USDA Forest Service, 2018).”

P4, L6: maybe here it would be good to indicate what is the proportion of the total burned area comprised by these fires that you characterize.

Reply: We added this information in the revised section.

P5. In 2.4, what is the purpose of applying a kernel function to fit (. . .see the rest in Lines 17-19)?

Reply: The original dataset of cross-boundary transmission zones was comprised of two sets of ignitions: those ignited on land tenure 1 and burned into land tenure 2 (attributed with only the amount of fire that they send to land tenure 2); and the opposite (from land tenure 2 to land tenure 1). To convert ignitions into transmission zones we had to use an interpolation technique to project the values of fire transmission from all neighboring ignitions into a continuous surface that cover also the parts of the landscape without ignitions. Results can be seen in Figure 7 (b-d). We modified the whole sections 2.3 and 2.4 to clarify their meaning to the readers.

P5, L19: how was the NTFI calculated? What is the reference?

Reply: Members of our team have created a toolbox named XFire that can do all the necessary processing. It hasn't been released or published yet. We provided additional explanation of how the self-burning index was calculated – to simply put, it required spatial GIS calculations of the simulated fire perimeters with land tenure data and ignition points. Please refer to the revised section 2.3.

P6, L2: I don't understand the purpose of Scott and Burgan's reference.

Reply: The input data for the production of Figure 9c were the fuel model classes of Scott and Burgan (LANDFIRE data). We moved the reference in the caption of Figure 9.

P7, L21: remove "spatially". Redundant.

Reply: The word "spatially" has been removed.

P8, L1: don't understand, probably because NTF index was not explained in the manuscript.

Reply: We added a detailed explanation in part 2.4 on how we estimated the self-burning index.

P10, L6: if you use "was", follow it by "large differences were".

Reply: Corrected.

P10, L23: I believe it is "shrub fuels account for three quarter of the fuel models in some states".

Reply: Corrected.

P11, L29: Why do you need probabilistic estimations? No reason provided to the reader.

Reply: The question was that given a hypothetical fire at a given location/day-in-year and size, is it a lightning or human fire? The answer is we can't know for sure. However, given the historical info, we have seen historically that such fires are 60% of the time lightning caused. So, we can pick a random Bernoulli number with this probability to ascertain whether to assign lightning cause to this fire or not. At any given point and time (day-in-year) an ignition could be lightning with probability p and human with probability 1-p. So given a simulated ignition, this ignition is going to be lightning caused p% of the time. Notice, we are not simulating ignitions, but rather given an ignition we are deciding whether what was the most likely cause of that fire. Below are the are boxplots showing observed (human or lightning) fires vs the estimated probability for every GACC. We rephrased the sentence to provide additional info to the readers, including an additional figure in the Appendix.

Example figure 2: Boxplots showing observed (human or lightning) fires vs the estimated probability for every GACC. (see second figure after the comments)

P12, L7-9: something wrong with the sentence.





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Reply: Rephrased.

P12, L13: extend?

Reply: Corrected to “extent”.

P12, L15-18: something wrong with the sentence.

Reply: Rephrased.

P13, L23: what does “reduction of fire deficit” mean?

Reply: It was redundant and out of scope of the paper. It is now removed.

Figure 9: need to mention that the figure concerns fireshed characteristics, otherwise revise the location of the Figure in the document.

Reply: The paneled figures represent fireshed characteristics of each state. We revised the figure caption.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-56/nhess-2019-56-AC2-supplement.zip

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-56, 2019.

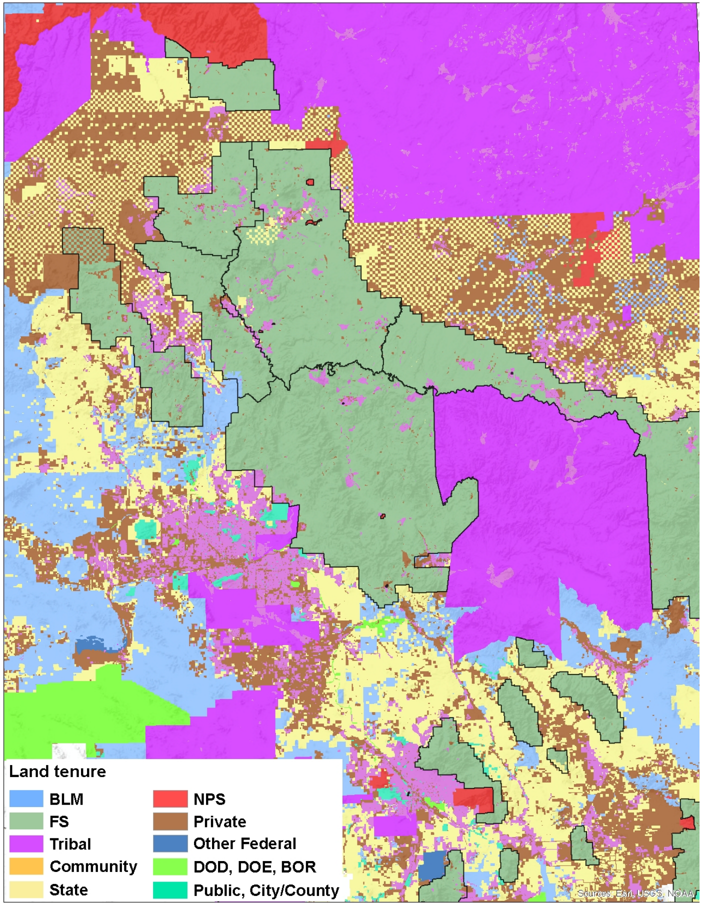


**Fig. 1.**





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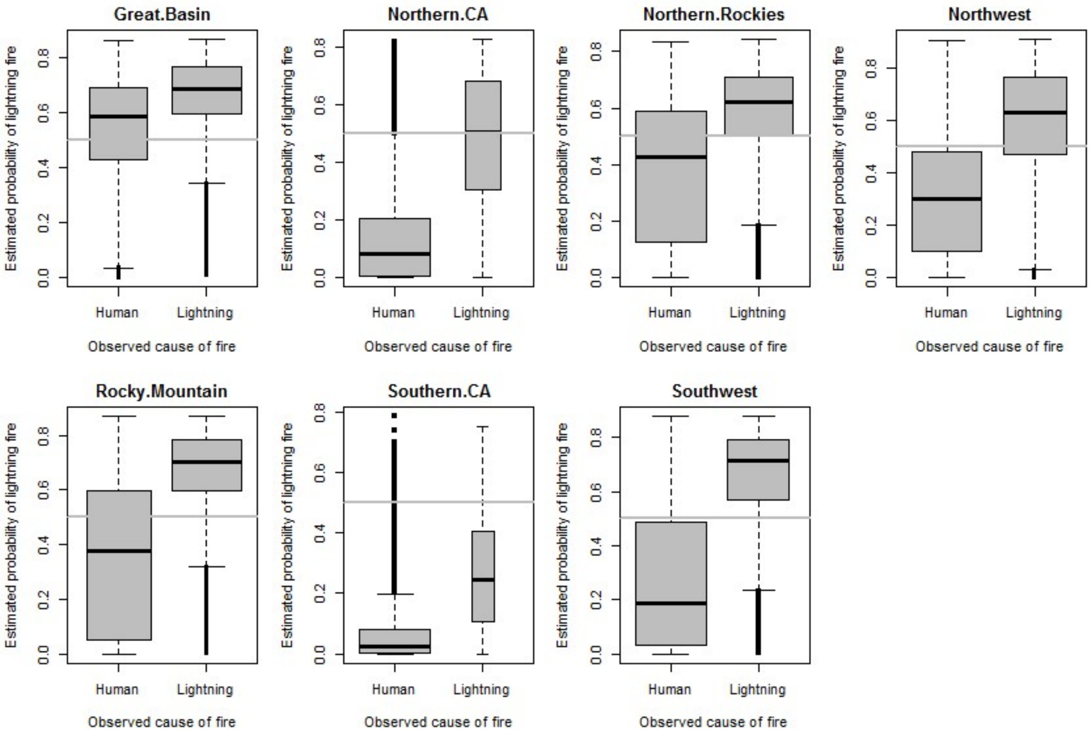


**Fig. 2.**



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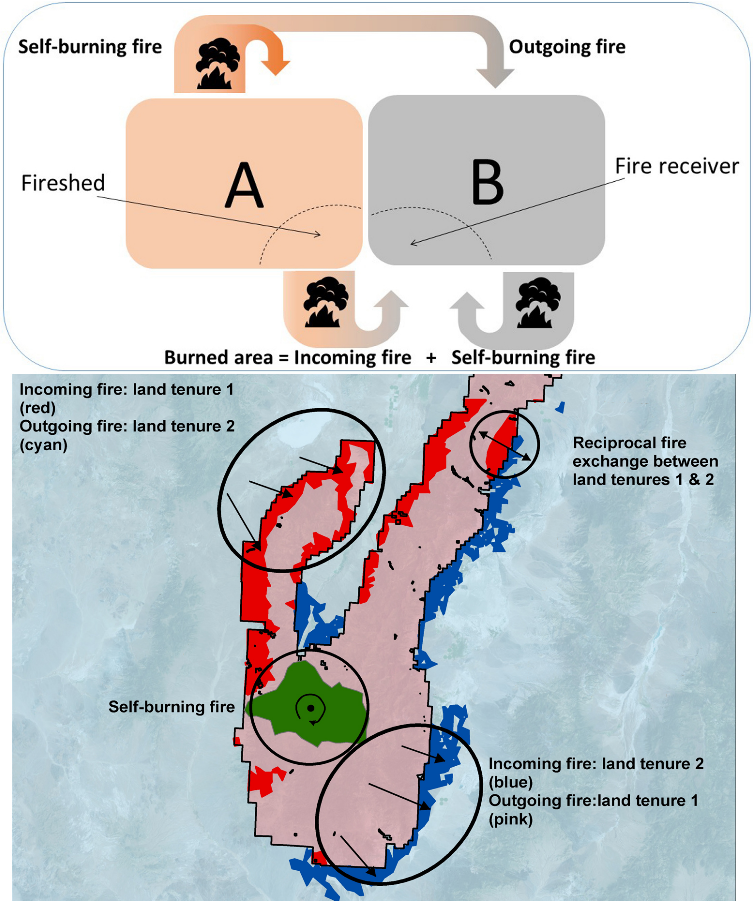


Fig. 3.



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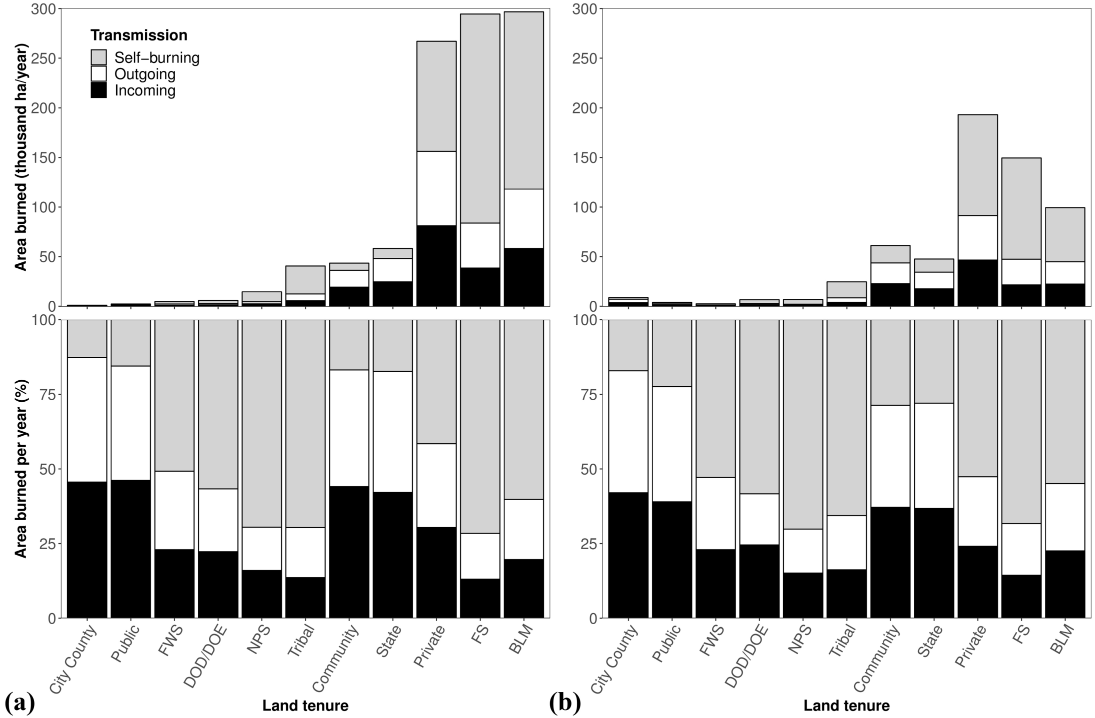
300
250
200
150
100
50
0
Area burned (thousand ha/year)
Transmission
Self−burning
Outgoing
Incoming
100
75
50
25
0
Area burned per year (%)
City County
Public
FWS
DOD/DOE
NPS
Tribal
Community
State
Private
FS
BLM
Land tenure
(a)
(b)

**Fig. 4.**

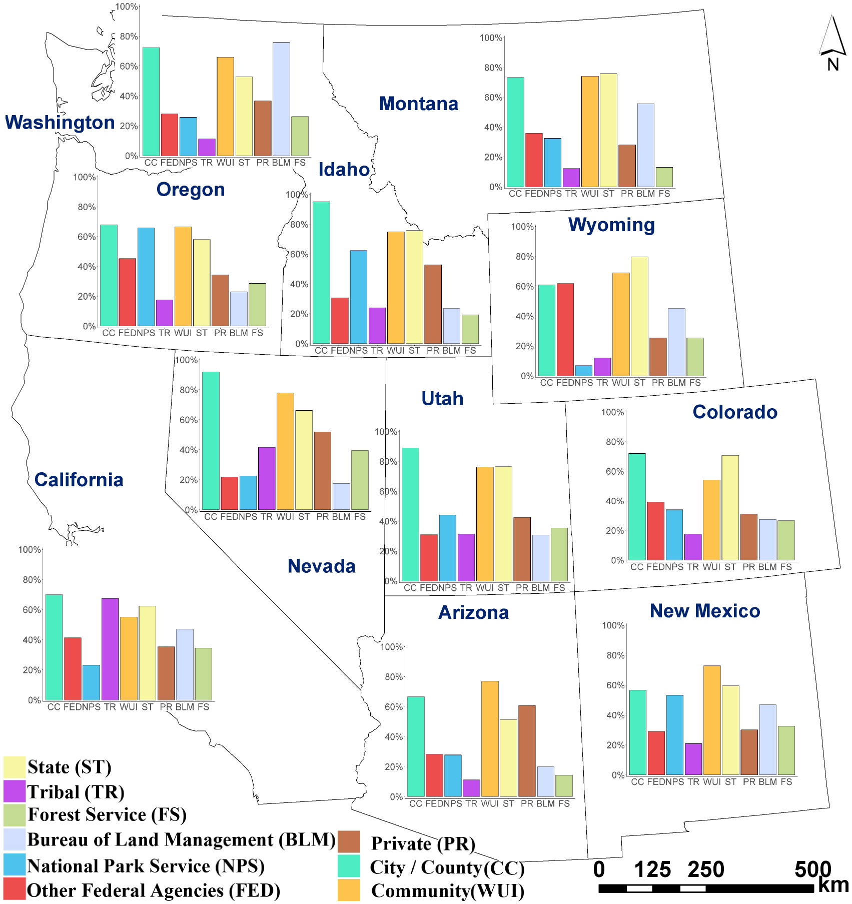


Fig. 5.



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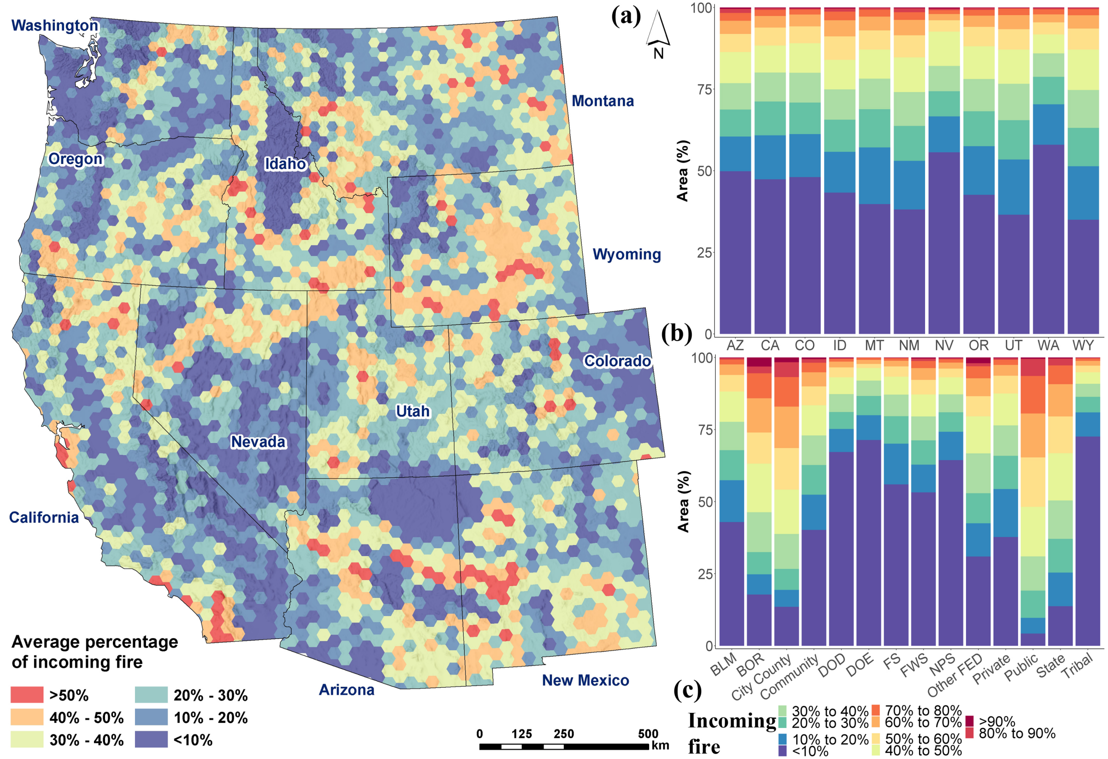


Fig. 6.



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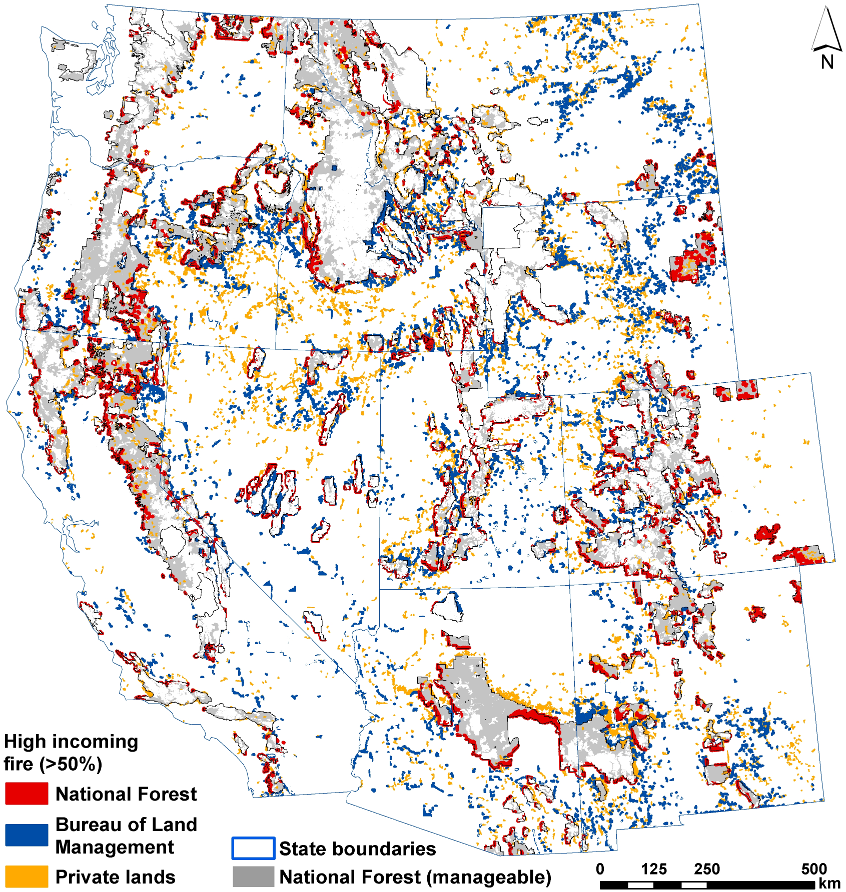


Fig. 7.





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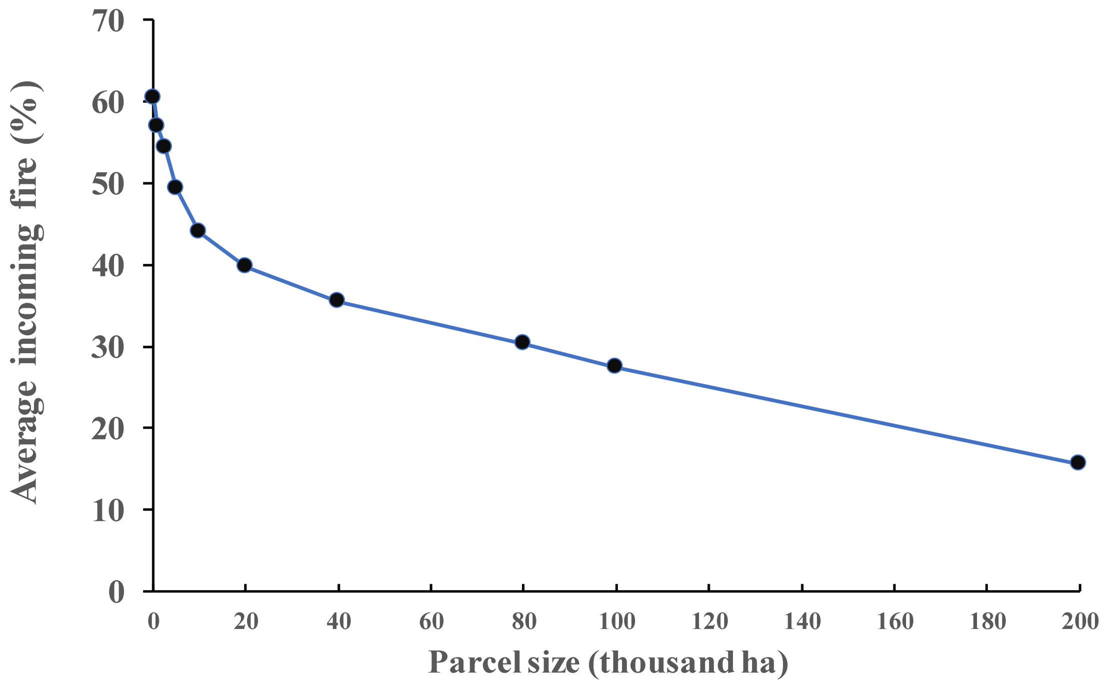


Fig. 8.



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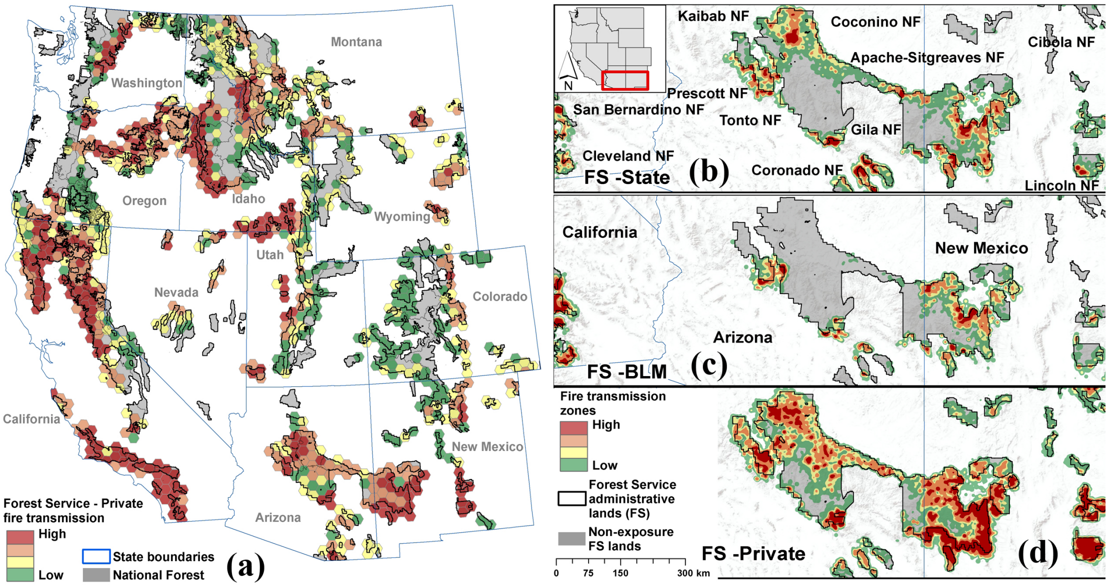


Fig. 9.



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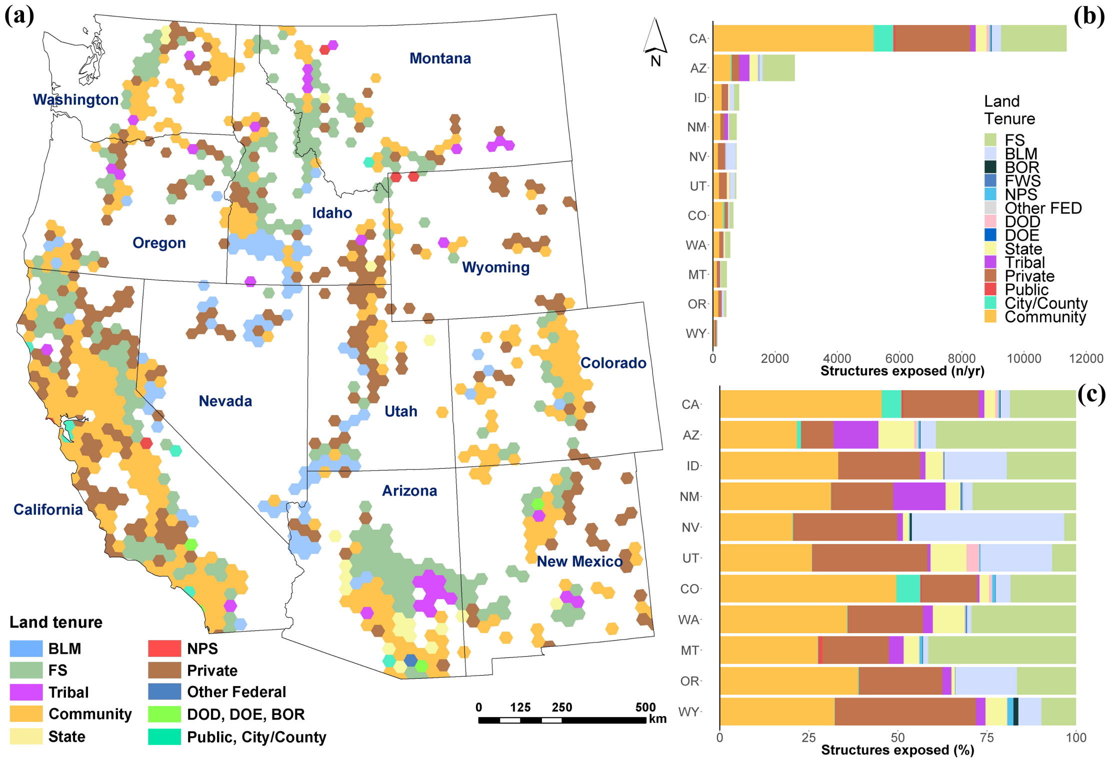
(a)
Washington
Montana
Oregon
Idaho
Wyoming
Nevada
Utah
Colorado
California
Arizona
New Mexico
N
Land tenure
BLM
FS
Tribal
Community
State
NPS
Private
Other Federal
DOD, DOE, BOR
Public, City/County
0 125 250 500 km
(b)
CA
AZ
ID
NM
NV
UT
CO
WA
MT
OR
WY
Land Tenure
FS
BLM
BOR
FWS
NPS
Other FED
DOD
DOE
State
Tribal
Private
Public
City/County
Community
0 2000 4000 6000 8000 10000 12000
Structures exposed (n/yr)
(c)
CA
AZ
ID
NM
NV
UT
CO
WA
MT
OR
WY
0 25 50 75 100
Structures exposed (%)

Fig. 10.

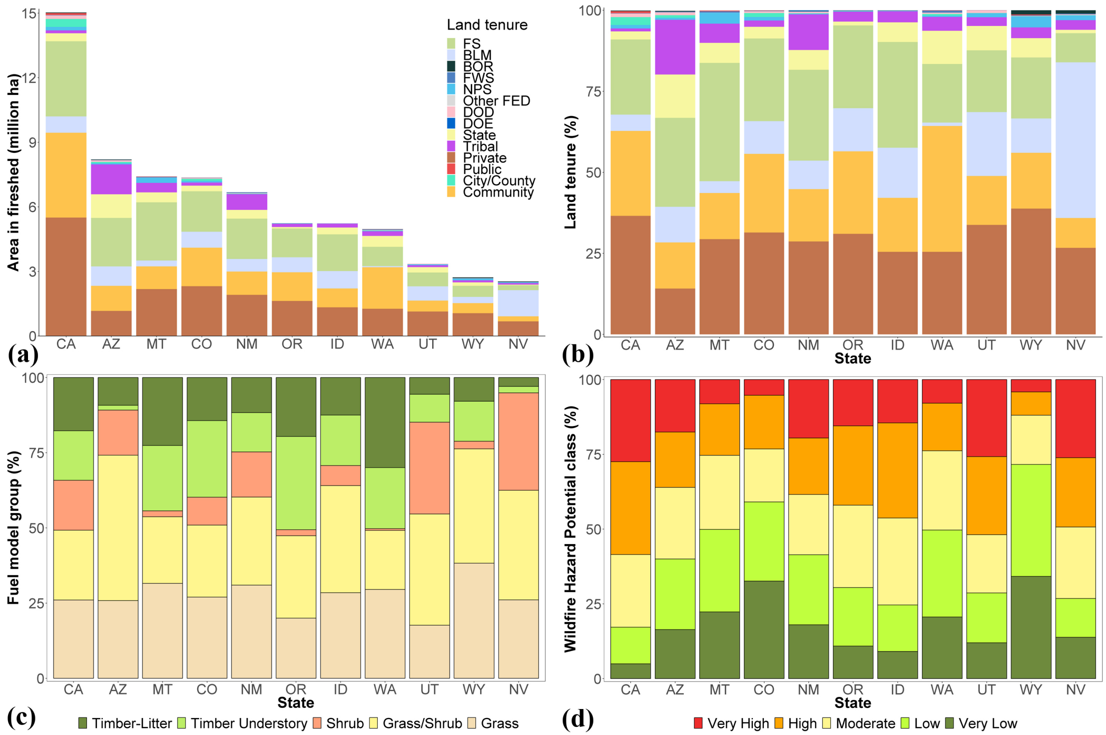


Fig. 11.





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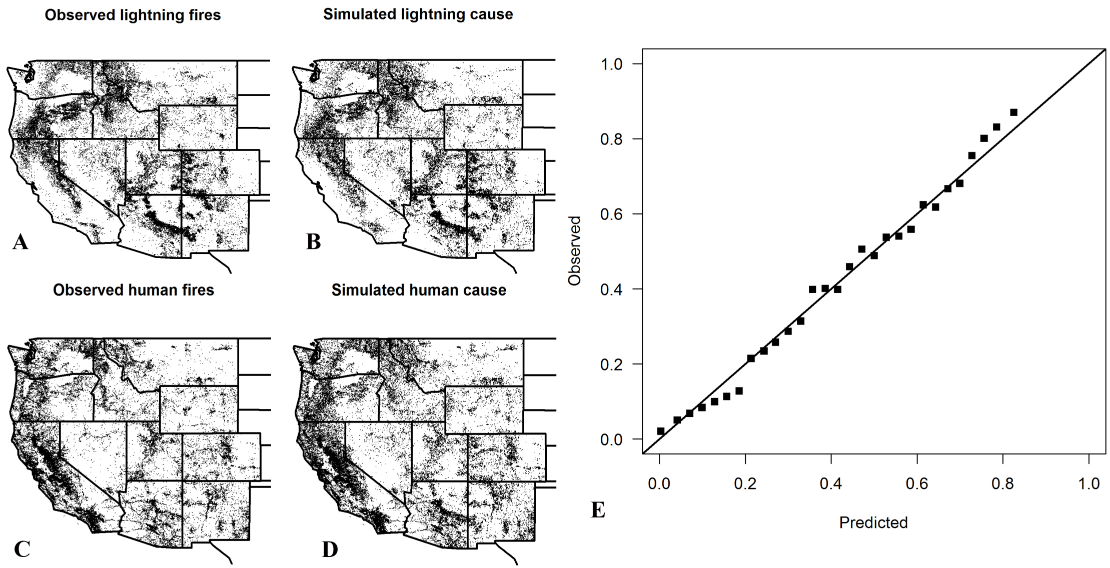
Observed lightning fires
Simulated lightning cause
Observed human fires
Simulated human cause
A
B
C
D
E
Observed
Predicted
0.0
0.2
0.4
0.6
0.8
1.0

**Fig. 12.**

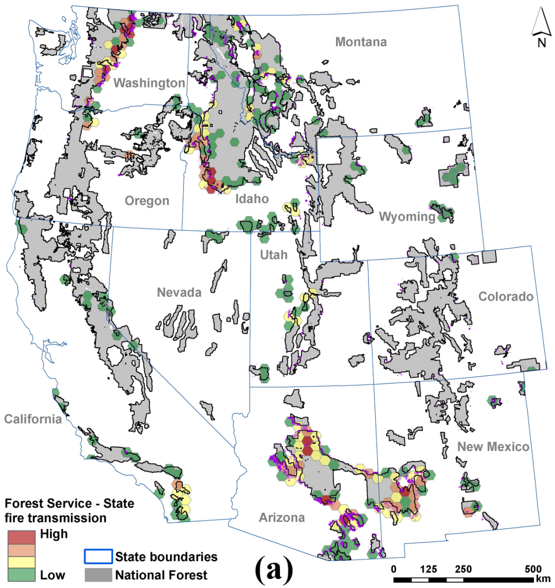


**Fig. 13.**



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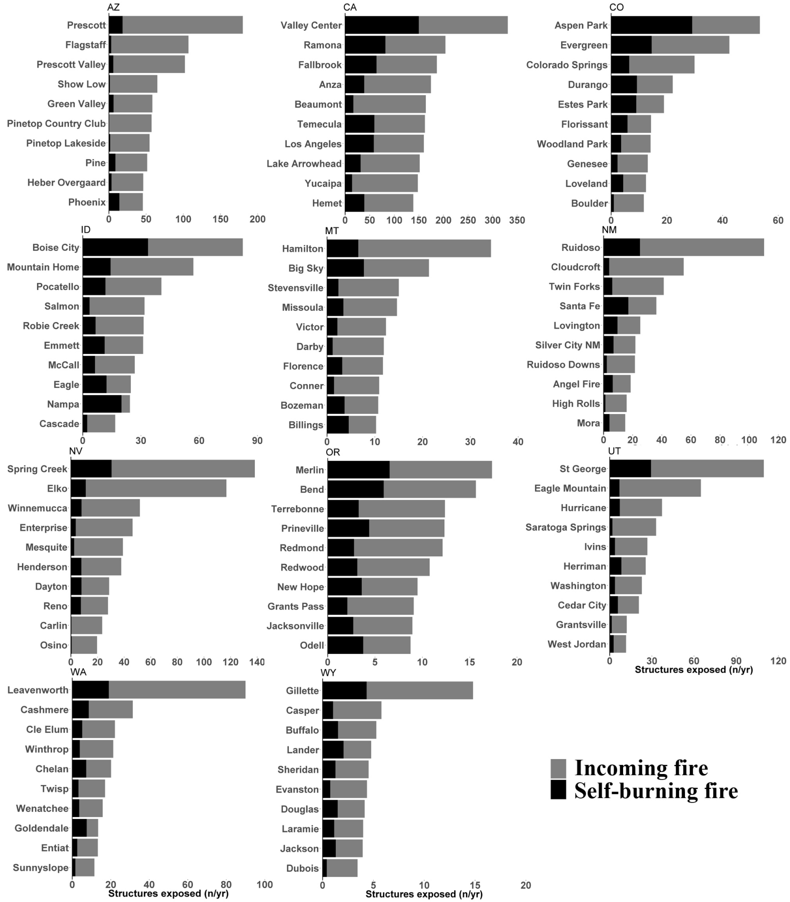


**Fig. 14.**



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