The Chauçer White Papers

North American Wildfire Risk

A study on the impact of people and environment on severe wildfire risk

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Purpose and Scope

Wildfires, particularly North American wildfires, are a key risk for our industry. For reasons ranging from urban development patterns to climate change, the danger they pose is growing. While many wildfire catastrophe models exist, they are relatively immature to other peril models and are not widely used by either the insurance or reinsurance markets. Given the risk is growing and confidence in the modelling has not matured, partly due to current regulatory restrictions, we need to better understand trends in wildfires and what these mean from both an industry and a view of risk perspective.

US West Coast (California, Oregon, and Washington) wildfires, and in particular California wildfires, are some of the most extensively studied. As such, we compiled a literature review of the published science, identifying the key factors responsible for these wildfires, how these trends are changing in the West Coast, and how this is driving an increase in wildfire risk. We then looked at which other regions in North America were exposed to the factors contributing to these fires, and hence, could be locations of high risk for future wildfires.

While we recognise that wildfires are a global risk, we have limited the scope of this paper to examining the North American risk.

This paper will:

— Section 1
Provide an overview of the trends increasing wildfire risk

— Section 2
Outline where we think could be next for major wildfire risk

— Section 3
Summarise findings and takeaways

There are two broad categories of trends that we believe are driving increased wildfire risk:

ENVIRONMENTAL FACTORS

1 Wildfire season

2 Rainfall patterns

3 Katabatic winds

4 Bark Beetle infestations

PEOPLE FACTORS

5 Forest management and fire suppression methods

6 People living in increasingly "at risk" regions

1 Wildfire season

Research suggests that climate change is driving change across the wildfire season, especially:

- The number of wildfire days is expected to increase significantly
- There are likely to be more large fires later in the season (September to December)

Increasing wildfire days

Research suggests that the number of wildfire days is likely to increase significantly. The extent of this increase depends on carbon dioxide emissions in the coming years. Currently there are 36 wildfire days a year. Even under an intermediate emissions scenario, the most likely scenario currently projected, the number of wildfire days would increase by 61% to 58 days. Under a high emissions scenario, this would almost double, to 71 days.[1]

1. Dong, C., Williams, A.P., Abatzoglou, J.T., Lin, K., Okin, G., Gillespie, T., Long, D., Lin, Y., Hall, A. and MacDonald, G. (2022) The season for large fires in Southern California is projected to lengthen in a changing climate. Communications in Earth and Environment 3, 22. https://doi.org/10.1038/s43247-022-00344-6

Later Season Fires

Research suggests that there is an increased likelihood of large fires throughout the year based on current trends and climate projections. While different researchers have specifically identified different months as being most acute, they seem to agree that the period between September and December is likely to be the highest risk.

A 2022 research study on large fires in Southern California using climate change projections, shows a significantly increased likelihood of large fires from November to March compared to today, particularly under a high emissions scenario. This difference is particularly acute in November and December, a period already known to generate severe fires (Thomas 2017, Camp 2018). See Figure 3 below.[2]

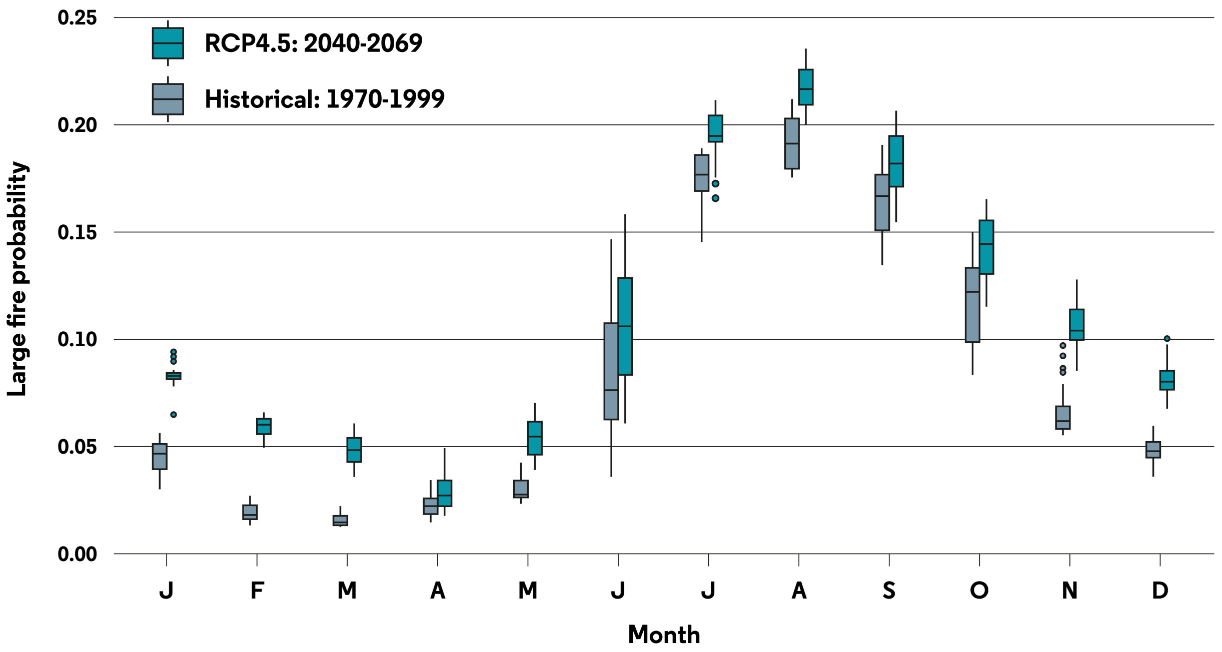


Figure 3. The figure above shows the historical large fire probability (LFP) from 1970-1999 as compared with the LFP projection under a Representative Concentration Pathway (RCP) scenario 4.5 .[3]

2,3. Dong, C., Williams, A.P., Abatzoglou, J.T., Lin, K., Okin, G., Gillespie, T., Long, D., Lin, Y., Hall, A. and MacDonald, G. (2022) The season for large fires in Southern California is projected to lengthen in a changing climate. Communications in Earth and Environment 3, 22. https://doi.org/10.1038/s43247-022-00344-6

This shift to later season wildfires is also noted in the report for California's Fourth Climate Change Assessment. This report cites a combination of factors, including a wet previous winter that promoted fuel growth, continued drought that dried this fuel and killed trees, combined with high winds that spread the fires during the latter part of the season.[4]

Other studies report a significant historical trend towards increased fire risk in autumn (September to November) across most of California in response to a warming trend and a modest reduction in precipitation observed over the 1979–2018 period.[5] This research suggests that wind events will coincide with the presence of dry fuels thereby increasing the potential for wildfire late in the season.

This research is supported by additional studies from 2021 which suggest that the rainy season in California has become progressively delayed, leading to the coincidence of extremely dry vegetation and strong downslope (katabatic) winds, exacerbating wildfire risk later in the autumn.[6][7]

4. Bedsworth, L., Cayan, D., Franco, G., Fisher, L., and Ziaja, S. (2018). California's Fourth Climate Change Assessment: State Wide Summary Report. https://climateassessment.ca.gov/
5. Goss, M., Swain, D. L., Abatzoglou, J. T., Sarhadi, A., Kolden, C. A., Williams, A. P., & Diffenbaugh, N. S. (2020). Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. Environmental Research Letters, 15(9), 094016. https://doi.org/10.1088/1748-9326/ab83a7
6. Luković, J., Chiang, J. C. H., Blagojević, D., & Sekulić, A. (2021). A later onset of the rainy season in California. Geophysical Research Letters, 48, e2020GL09350. https://doi.org/10.1029/2020GL090350
7. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843

2 Rainfall patterns

Evidence suggests rainfall patterns are changing in California. The two main takeaways include:

- **Changing patterns of rainfall:** Rainfall appears to be concentrating in the core months (December to March) at the expense of the shoulder months, especially September to November
- **Implications for wildfires:** This is likely to lead to a longer wildfire season and, potentially, larger fires

Changing patterns of rainfall

There is evidence for significant changes in rainfall patterns across California. Research suggests that California's wet season is becoming shorter and sharper.[8] Precipitation data from between 1960 and 2019 shows a significant decrease in autumn rainfall (September – November) and a delayed onset of the rainy season, which now starts almost a month (approximately 27 days) later than it once did.[9] As a consequence, precipitation in California has become concentrated in the rainy season months between December and March, at the expense of the shoulder seasons (primarily autumn) as shown in Figure 2.[10]

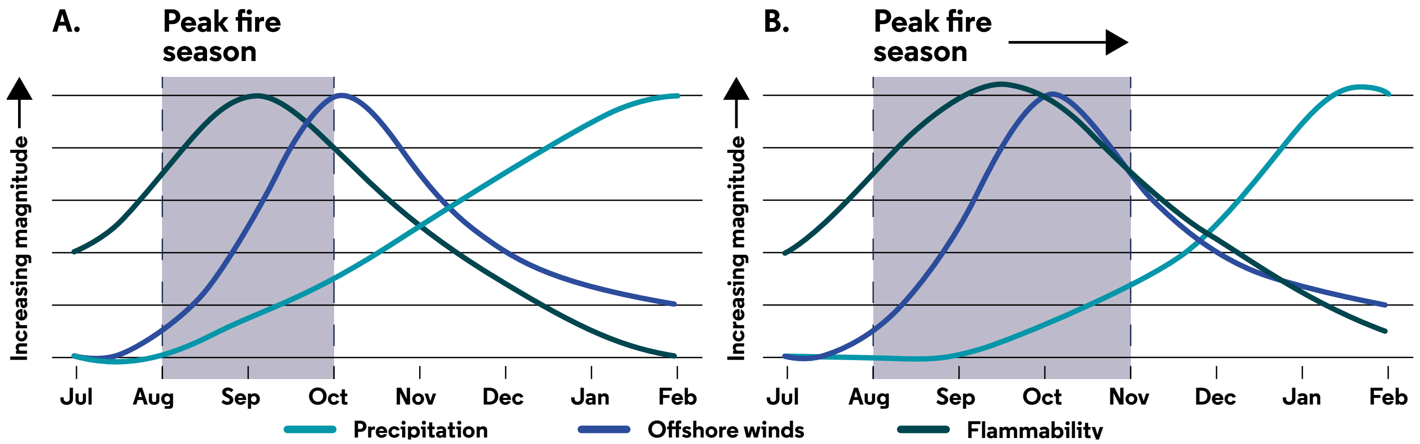


Figure 2. This figure illustrates how a delay in autumn precipitation can lead to an extended fire season (shown in Figure 2b) causing an overlap between dry vegetation (with increased flammability) and peak wind conditions, which can lead to an increase in the duration and severity of the peak fire season. Firstly, lower precipitation leads to extended periods of negative water balances with low moisture levels in dead and dormant vegetation (including bark beetle infested woodland, to be discussed later). This means drier fuels and increased wildfire severity in the event of fire ignition.[11]

8,10,11. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843
9. Luković, J., Chiang, J. C. H., Blagojević, D., & Sekulić, A. (2021). A later onset of the rainy season in California. Geophysical Research Letters, 48, e2020GL09350. https://doi.org/10.1029/2020GL090350

Research shows a decline in summer precipitation from 1979 to 2016 across many forested areas in the western United States which are strongly associated with burned area variations. The study suggests that precipitation during the fire season exerts the strongest control on burned areas either directly through wetting or indirectly via VPD (vapour pressure deficit - a measure of water vapour in the air). Furthermore, this research indicates that if these trends persist, a decrease in summer precipitation and the associated greater summer aridity would lead to a greater burned area across the western US.[12]

Secondly, delayed autumn precipitation results in the dry season coinciding with the arrival of the hot, dry offshore winds. This increases the overlap period between extremely dry vegetation and strong wind conditions and significantly amplifies wildfire risk in the autumn.[13]

12. Holden, Z. A., Swanson, A., Luce, C. H., Jolly, W. M., Maneta, M., Oyler, J. W. and Affleck, D. (2018). Decreasing fire season precipitation increased recent western US forest wildfire activity. Proceedings of the National Academy of Sciences, 115(36), E8349-E8357.https://doi.org/10.1073/pnas.1802316115
13. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843

3 Katabatic Winds

- Katabatic, or special, winds occur on the West Coast of the US and in areas of similar geography
- The interaction between katabatic winds and other wildfire drivers is complex
- Global warming is impacting this relationship, so the system is in flux

What are katabatic winds and why do they occur?

Katabatic winds are winds that form due to temperature and altitude differences. These typically occur when a cool, dry air mass flows downslope from a high-elevation region towards a lower coastal plain. As the air sinks, it is compressed and becomes warmer, losing relative humidity and becoming drier. See Figure 1 below.[14]

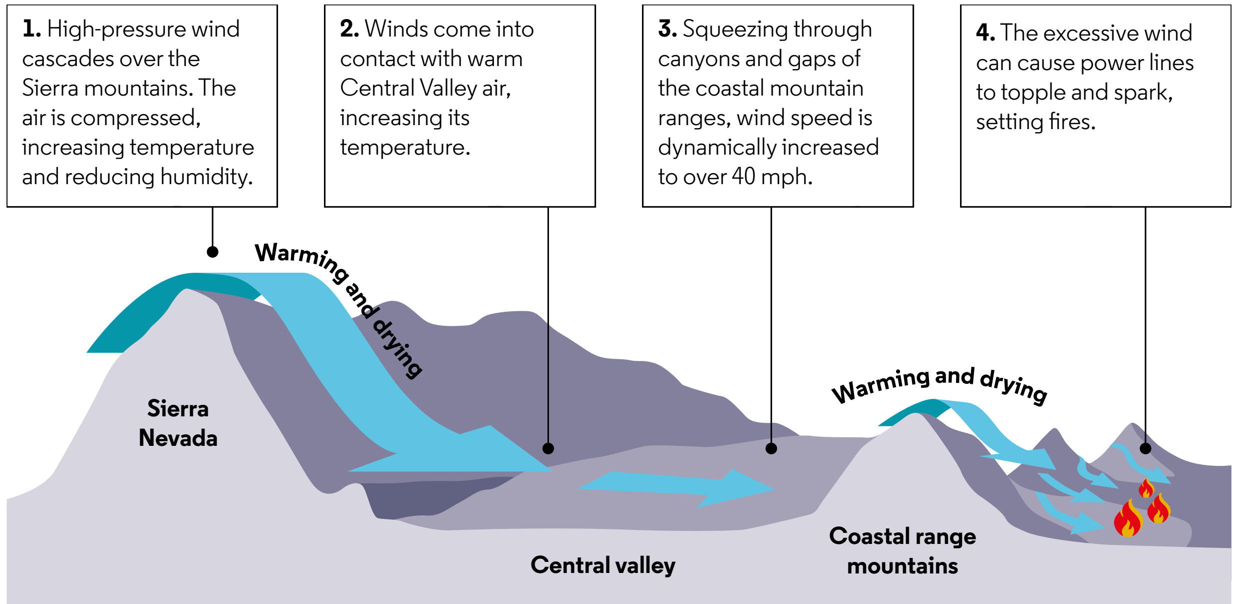


Figure 1. The infographic above provides an illustration of katabatic wind formation in Northern California[15]

14,15. Alexander, Kurtis and Blanchard, John. "Are infamous Diablo winds responsible for recent wildfires?" The San Francisco Chronicler. 28 October 2019. Accessed 24 October 2022. https://www.sfchronicle.com/environment/article/Are-infamous-Diablo-winds-responsible-for-recent-14570132.php

The role of the geography of the western US

The physical geography of the West Coast of the US gives rise to katabatic winds. These winds flow from the interior highlands and are funnelled toward the Californian coastal ranges by the Sierra Nevada and Rocky Mountain ranges. The local topography, particularly the valleys, channels the air as it descends towards the sea.[16] In Northern California, they are called Diablo (devil) winds and in Southern California, they are more commonly referred to as the Santa Ana winds.

Impact of katabatic winds on wildfires

Katabatic winds increase both the risk of fires starting and their severity and spread once they start. Because these winds are dry and hot, they quickly reduce the moisture in wildfire fuels such as grasses, shrubs and trees; and given their speed and strength, they also fan the flames of any fire once it begins and cause them to spread quickly.

In a 2021 study of "megafires" (defined here as fires greater than 36,400 ha) it was found that unusual, extreme winds played a critical role in initiating and propagating the fires.[17] A second study showed the impact of this type of wind in driving fire growth in both the Washington/ Oregon fires of 2020,[18] while spatial analysis in a third paper indicates a strong correlation between regional fires in Southern California and the preceding incidence of katabatic winds.[19]

16. Li, X., Zheng, W., Pichel, W. G., Zou, C.-Z. and Clemente-Colón, P. (2007), Coastal katabatic winds imaged by SAR. Geophysical Research Letters, 34, L03804. https://doi.org/10.1029/2006GL028055
17. Potter, B. and McEvoy, D. (2021) Weather factors associated with extremely large fires and fire growth days. Earth Interactions. 25(1): 160-176. https://doi.org/10.1175/EI-D-21-0008.1.
18. Mass, C. F., Ovens, D., Conrick, R., and Saltenberger, J. (2021). The September 2020 Wildfires over the Pacific Northwest. Weather & Forecasting, 36(5), 1843–1865. https://doi.org/10.1175/WAF-D-21-0028.1
19. Kolden, C. A., & Abatzoglou, J. T. (2018). Spatial distribution of wildfires ignited under katabatic versus non-katabatic winds in Mediterranean Southern California USA. Fire, 1(2), 19. https://doi.org/10.3390/fire1020019

The impact of katabatic winds is normally greatest in the autumn months, when vegetation is already dry after a long, hot summer period and before the onset of the winter rainy season. When the seasonal rains arrive, fire incidence appears to decrease, as demonstrated in Figure 2.[20] However, these seasonal rains are now tending to begin later in the year and a longer wildfire season, which lasts into the winter months, is envisaged.

Impact of climate change on katabatic winds

Differential warming driven by climate change will impact all katabatic special winds. While research is still limited in this area, there is evidence for southern California that climate change will impact katabatic winds in two important ways. Firstly, that total frequency of Santa Ana winds will decrease as the pressure gradient between the high mountains and the valleys becomes smaller. This will reduce the number of fires driven by these special winds in southern California.

Secondly, the main wind season from November to January is expected to become more prominent in southern California with the most severe wind days having stronger winds, but being fewer in total number. This is likely to result in the average fire being less impacted by katabatic winds, but a higher risk of the most severe fires.[21]

This change is likely to contribute to a lengthened peak wildfire season that pushes the most severe fires into the winter.[22]

20. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843
21,22. Guzman-Morales, J., & Gershunov, A. (2019). Climate change suppresses Santa Ana winds of Southern California and sharpens their seasonality. Geophysical Research Letters, 46, 2772– 2780. https://doi.org/10.1029/2018GL080261

4 Beetle infestations

Insect infestations are a growing problem in American woodlands.

Specifically:

- Climate change has allowed species which infest trees to expand their range
- Climate change also impairs trees' ability to fight infestations
- Infestations kill trees and increase forest flammability

A growing threat of beetle infestations

Insect infestations are an increasing problem in American woodlands, where climate change has improved survival rates and enabled the migration of invasive species to higher latitudes and elevations, which were previously inhospitable to them.[23] Figure 4 on the following page shows some of the major beetle infestations across the West Coast of the US and Canada.[24]

23. Bentz, B., Régnière, J., Fettig, C., Hansen, E., Hayes, J., Hicke, J., Kelsey, R., Negrón, J. and Seybold, S. (2010) Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects, BioScience, 60(8), 602–613, https://doi.org/10.1525/bio.2010.60.8.6
24. Meddens, A., Hicke, J., and Ferguson, C. (2012) Spatiotemporal patterns of observed bark beetle-caused tree mortality in British Columbia and the Western United States. Ecological Applications, 22(1), 1876-1891, https://doi.org/10.1890/11-1785.1

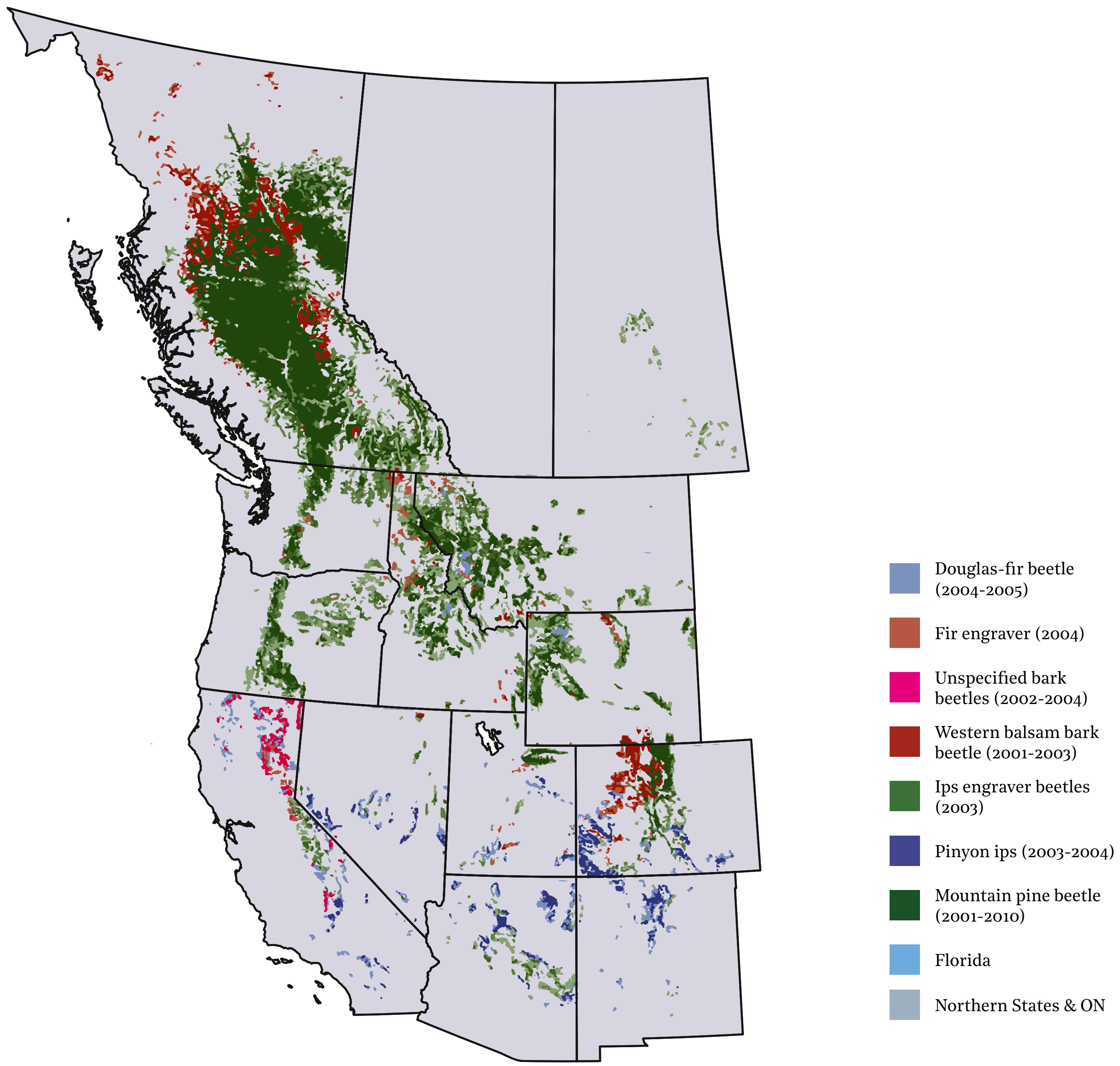


Figure 4. Bark beetles' impacts on forests across the Western US and British Colombia[25]

25. Meddens, A., Hicke, J., and Ferguson, C. (2012) Spatiotemporal patterns of observed bark beetle-caused tree mortality in British Columbia and the Western United States. Ecological Applications, 22(1), 1876-1891, https://doi.org/10.1890/11-1785.1

Climate change limits trees' ability to defend against pests

Climate change may result in an increase in droughts, which can impede trees' ability to fight insect infestations. The mechanism works as follows. During times of water stress, trees close their stomata (pores). This serves to conserve water but it also causes a reduction in carbon assimilation. This, in turn, inhibits a plant's functions for growth, defence, and tissue repair - and ultimately affects a tree's ability to respond to bark beetle invasions.[26]

Damaged trees contribute to wildfires

Many bark beetles are native to North America and they impact wildfires in a number of ways.

- Trees colonised and killed by bark beetles rapidly dry out and lose most of their water content within a year following a fatal attack[27]
- Beetle attacks generally increase the emission of naturally occurring flammable compounds (terpenes) from conifer trees, leading to more intense fires[28]
- Ultimately, dead wood from beetle-killed trees is transferred to the forest floor, leading to increased ground-based fuel load[29]

When looking at the impact of destructive insect species, such as beetles, on forest health and wildfires, it is important to consider the type and distribution of different tree species that may be affected.

26. Bentz, B., Régnière, J., Fettig, C., Hansen, E., Hayes, J., Hicke, J., Kelsey, R., Negrón, J. and Seybold, S. (2010) Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects, BioScience, 60(8), 602–613, https://doi.org/10.1525/bio.2010.60.8.6
27,28,29. Fettig, C.J., Hood, S, J,. Runyon, J. B. and Stalling, C. M. (2021). Bark beetle and fire interactions in western coniferous forests: Research findings. Fire Management Today. 79(1): 14-23. https://www.firescience.gov/projects/20-1-01-14/project/20-1-01-14_FMT_2021.pdf

Table 1 provides a summary of the common trees affected by different beetle species and the impacts on fire behaviour. Importantly, research also notes that "firefighters should anticipate the potential for unusual fire behaviour in beetle-affected forests and the unique suppression challenges that can result."[30] For example, trees may remain standing with their needles in tact for two or three years after an attack.

Common name	Scientific name	Common host(s)	Current knowledge of effects on wildfire behaviour and severity *
Mountain pine beetle	Dendroctonus ponderosae	Whitebark pine, lodgepole pone, limber pine, sugar pine, western white pine, ponderosa pine	High
Douglas-fire beetle	Dendroctonus pseudotsugae	Douglas-fir	Moderate
Spruce beetle	Dendroctonus rufipennis	Engelmann spruce, white spruce, lutz spruce	Moderate
California fivespined ips	Ips paraconfusus	Lodgepole pine, sugar pine, ponderosa pine	Low
Jeffrey pine beetle	Dendroctonus jeffreyi	Jeffrey pine	Low
Northern spruce engraver	Ips perturbatus	White spruce, lutz spruce	Low
Pine engraver	Ips pini	Lodgepole pine, jefferey pine, sugar pine, ponderosa pine	Low
Pinyon ips	Ips	Pinyon pine(s)	Low
West balsam bark beetle	Dendroctonus confusus	Sudalpine fire	Low
Western pine beetle	Dendroctonus brevicomis	Ponderosa pine, coulter pine	Low
Fir engraver	Scolytus ventralis	White fir, grand fir, california red fir	Low

* *Level (low, moderate, or high) defined in relation to knowledge of the effects imposed by mountain pine beetle outbreaks, which have been most intensively studied.*

Table 1. Beetle species in the Western US and the trees they tend to infect.[31]

30,31. Fettig, C.J., Hood, S, J,. Runyon, J. B. and Stalling, C. M. (2021). Bark beetle and fire interactions in western coniferous forests: Research findings. Fire Management Today. 79(1): 14-23. https://www.fs.fed.us/psw/publications/fettig/psw_2021_fettig006.pdf

5 Forest management

Background and History

The use and management of US wildlands has changed significantly since Europeans first settled. Where once fires burned naturally, the story of the 20th century has largely been one of suppression (often called "fire exclusion")*.

The suppression method emerged in the late 19th Century as a response to the Great Chicago Fire (and two other devastating nearby fires). It requires any buildup of heat and subsequent fire outbreak to be immediately extinguished, rather than allowing the wildfire to run its natural course and clear areas of low level vegetation. In 1935, the USDA Forest Service implemented the "10 AM Policy" - the objective of this was to stop the spread of any fire by 10 am the following day**.

Forms of management like these lead to build-up of vegetation and make forests denser. This, in turn, allows otherwise small, low-level fires to reach into the canopy and become fast moving, very severe wildfires. Aggressive fire suppression practices also result in the accumulation of deadfall and leaf litter which, again, contribute to the fuel load. Some of the greatest impacts in these management practices have been in the Rocky Mountain States, the Pacific States and the Southern US States.

The need for authorities to be seen to be taking action as fires encroach on urban areas, has led to a bias in favour of suppression. As a result, small towns and cities often put fires out before they reach the outskirts. This means many population centres are now encircled by dense vegetation, so when fires do strike, they are more severe.

While these practices have now changed in some regions, there are still many forests where large enough fires have not yet occurred to clear out this accumulated fuel.

***** Houghton, A.R., Hackler, J.L., and Lawrence, K.T. (2000). "Changes in Terrestrial Carbon Storage in the United States. 2: The Role of Fire and Fire Management". Global Ecology and biogeography, Vol. 9, No. 2, PP 145-170.
****** "Evolution of Federal Wildland Fire Management Policy". Review and Update of the 1995 Federal Wildland Fire Management Policy January 2001. National Park Service, U.S. Forest Service. January 2001.

Forest Management

Forest management is an alternative strategy to suppression and plays an important role in wildfire risk reduction. It typically involves prescription burning (controlled fires) and mechanical thinning techniques using chainsaws, masticators and other tools.[32] The goal is to clear out certain types of trees or densities of trees and remove understory (smaller trees, shrubs and vines).

Mechanical treatments which "remove understory fuels and thin the density of trees have two advantages over prescription burning - they can be done over a greater portion of the year and potentially can pay for themselves through timber sales"[33].

32 CALFIRE (2021) Fuel Reduction Guide. California Department of Forestry and Fire Protection. http://www.fire.ca.gov.
33 Keeley, J.E., Syphard, A.D. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. fire ecol 15, 24 (2019) https://doi.org/10.1186/s42408-019-0041-0

Results of Thinning and Burning

Prescribed burning and mechanical treatments do have a positive effect on fire behaviour. When a high intensity wildfire moves into an area that has been treated with mechanical thinning or controlled burns, fire behaviour often shifts from a crown fire to a surface fire with low intensity fire behaviour.[34] The Rim Fire is a good example of a high-intensity crown fire that settled down into low-intensity surface fires, upon entering a fuel managed area.[35]

However, a century of fire suppression means that there are still extensive tracts of forest with an excess fuel load. Furthermore, while many jurisdictions are improving their management of forests and fires, fragmented responsibility in the US means that neighbouring counties or tracts of forest can be managed very differently.

This can lead to a false sense of the risks that we face. If forests in the immediate vicinity of structures and population centres are well managed, but adjoining forests are poorly managed, then the risk of severe fire can still be high. If a fire is in the canopy and driven by strong winds then it might 'skip' across the well-managed forest and burn the structures.

Tree mortality is another important source of fuel load in forests, particularly when trees die following droughts or water stress. This happened in the recent California droughts, where over 100 million trees were lost. Typically, these areas of tree mortality will occur in large patches on the forest floor,[36]which can lead to a spatial concentration of deadwood material. If not removed, this can provide excess fuel load, leading to fires that are harder to control.

As tree mortality is often connected to the extreme weather events which are made more likely by climate change, we might expect this risk to increase, going forward.

34 CALFIRE (2021) Fuel Reduction Guide. California Department of Forestry and Fire Protection. http://www.fire.ca.gov.
35 Keeley, J.E., Syphard, A.D. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. Fire Ecology. 15, 24 (2019). https://doi.org/10.1186/s42408-019-0041-0
36 Stephens, S., Collins, B., Fettig, C., Finney, M., Hoffman, C., Knapp, E., North, M., Safford, H. and Wayman, R. (2018) Drought, Tree Mortality,and Wildfire in Forests Adapted to Frequent Fire, BioScience, 68(2), 77–88, https://doi.org/10.10

6

Population Growth In Wildfire Regions

Although California's population growth has slowed in recent years, it has almost doubled since 1970 – and some of the fastest growth has been in areas which have a high risk of wildfires.[37 38]

In a study published in 2022, researchers from Stanford and other universities mapped out where vegetation was creating the greatest fire risks across the western US. They then compared that map to where in the region people were moving into the wildland-urban interface (WUI).

"We were surprised to discover that the fastest rate of population growth by far has been in the areas with the highest fire risk. This includes several areas in California, Oregon, Washington and Texas."[39 40]

Population growth in wildland-urban interfaces increases the impact from wildfires and places more housing, people and infrastructure at risk. Between 1990 and 2010 the number of homes in US wildland-urban interfaces grew by 41%, from 30.8 to 43 million.

37 Fire Hazard Severity Zones Maps. CALFIRE. Accessed on 3 November 2022
https://osfm.fire.ca.gov/divisions/community-wildfire-preparedness-and-mitigation/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/
38 Moving East: California's Population Growth. California State Association of Counties. Accessed on 3 November
https://www.counties.org/csac-bulletin-article/moving-east-californias-population-growth
39 De Freitas, W. The fastest population growth in the West's wildland-urban interface is in areas most vulnerable to wildfires. (2022, February 7). The Conversation.
https://theconversation.com/the-fastest-population-growth-in-the-wests-wildland-urban-interface-is-in-areas-most-vulnerable-to-wildfires-173410
40 4. Rao, K., Williams, A., Diffenbaugh, N. Yebra, M. and Konings, A. (2022) Plant-water sensitivity regulates wildfire vulnerability. Nature Ecology & Evolution. 6:332-339.
https://doi.org/10.1038/s41559-021-01654-

This growth has continued over recent years and it is now estimated that there are approximately 50 million homes in the wildland–urban interface in the US, a number that is increasing by about a million houses every three years. This means that homes with an estimated value of $1.3 trillion, in 70,000 communities, are now at risk from the impacts of wildfires.

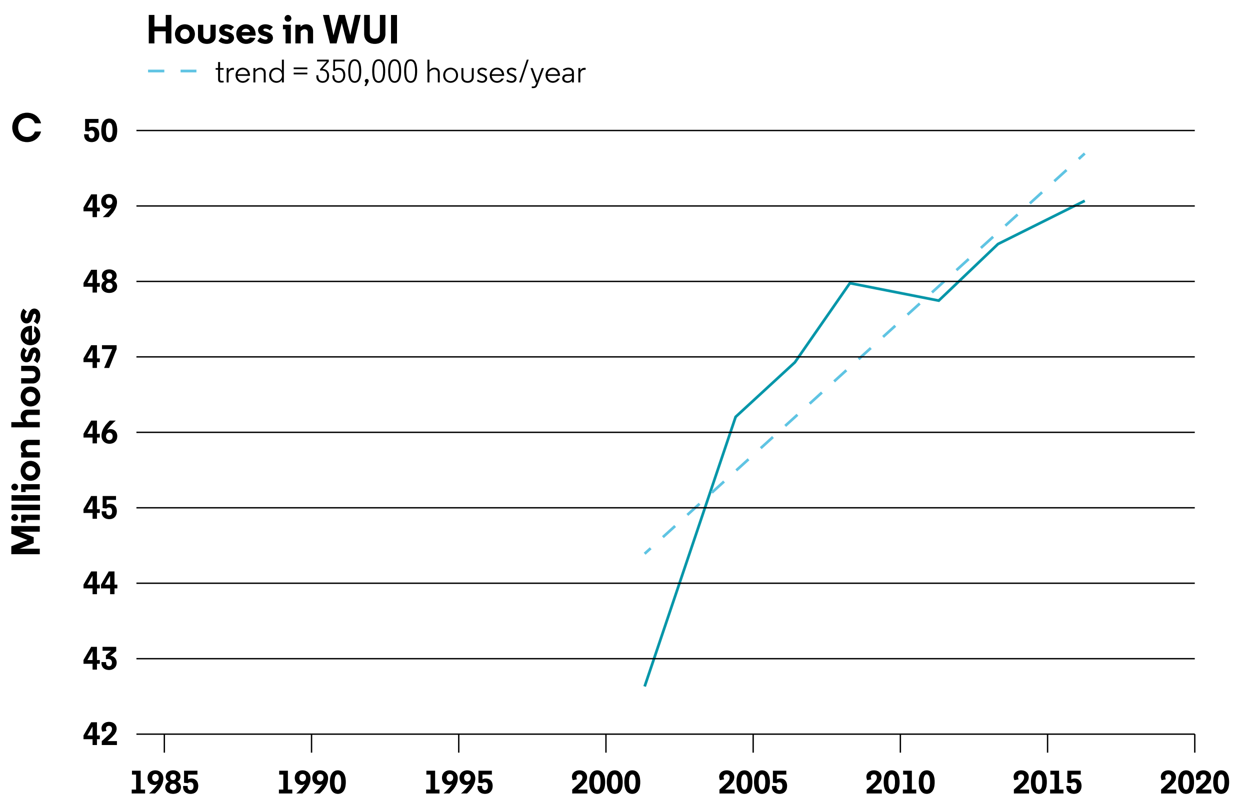


Figure 5. Wildfire trends in the USA. The number of homes in the WUI has risen quickly. (Burke et al., 2021).

Which areas could be affected by major wildfire next?

Our research shows that the West Coast of the US is something of a “canary in the coal mine,” or early predictor, when it comes to wildfire trends. What happens there may well happen in other areas of North America in the years and decades to come.

Overview of potential “high risk” regions

We’ve broken down the wildfire trends previously described into Table 2 and highlighted the regions of North America we believe have the greatest potential to be areas of major wildfire concerns. For each identified region, we have indicated whether or not we believe each wildfire trend applies.

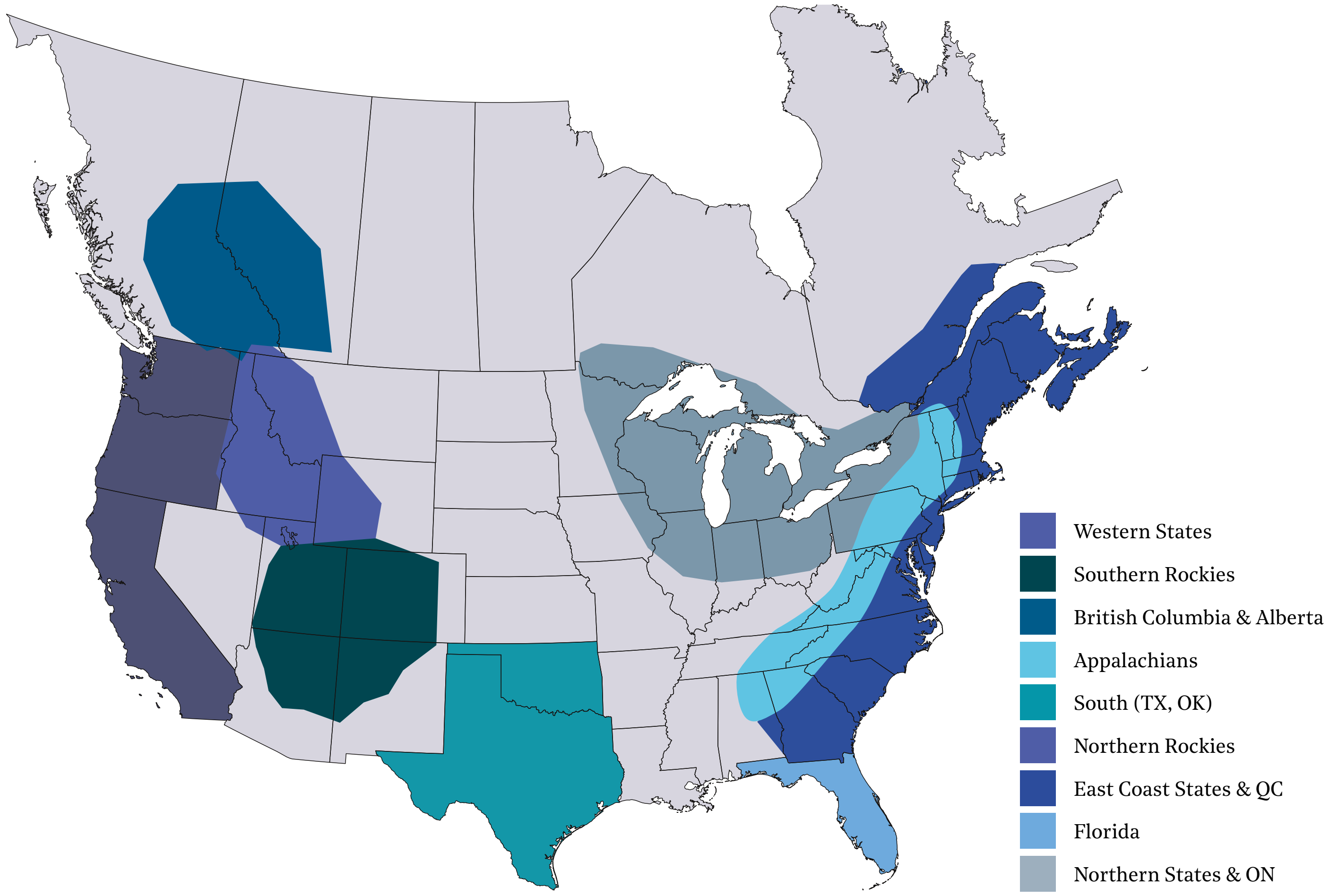


Figure 5. Potential high risk wildfire regions

Table 2. Potential high risk wildfire regions and corresponding environment and people factors

	Environment Factors				People Factors	
Regions	**Wildfire season** (longer droughts, and more severe heatwaves; delay in cooler autumn/winter temps)"	**Rainfall Pattern Changing**	**Special Winds** (Chinook, Santa Ana, etc)"	**Bark Beetles Infestations**	**Forest Management & Suppression** (unnatural fuel loads, and higher density)"	**Large Movement of People into WUI** (puts exposure into wildfire hazard areas)"
Western States	Y	Y	Y	Y	Y	Y
Southern Rockies	Y	Y	Y	Y		Y
British Columbia & Alberta	Y		Y	Y	Y	Y
Appalachians		Y	Y	Y	Y	Y
South (TX, OK)		Y		Y	Y	Y
Northern Rockies	Y		Y	Y		
East Coast States & QC			Y		Y	Y
Florida					Y	Y
Northern States & ON					Y	

Four key regions to watch

There are four main regions that we think have the highest potential for being severe wildfire risk. These include Southern Rocky Mountain states, Alberta and British Columbia, the Appalachians and the combined region of Texas and Oklahoma. All of these regions share some similarities to the West Coast of the US.

Region One: The Southern Rocky Mountain States (Colorado, New Mexico, Arizona and Utah)

Brief overview: High net worth individuals from California moving to "high risk" areas

The Southern Rockies are an area of high risk where we already see megafires, but there are pockets of risk which are changing.

We are seeing an influx of high net worth individuals moving from California to more remote areas of the Southern Rocky Mountain States. The reasons for this shift are varied but may include the cost of living crisis, covid-enabled working from home policies, desire for more space and greater affordability elsewhere.

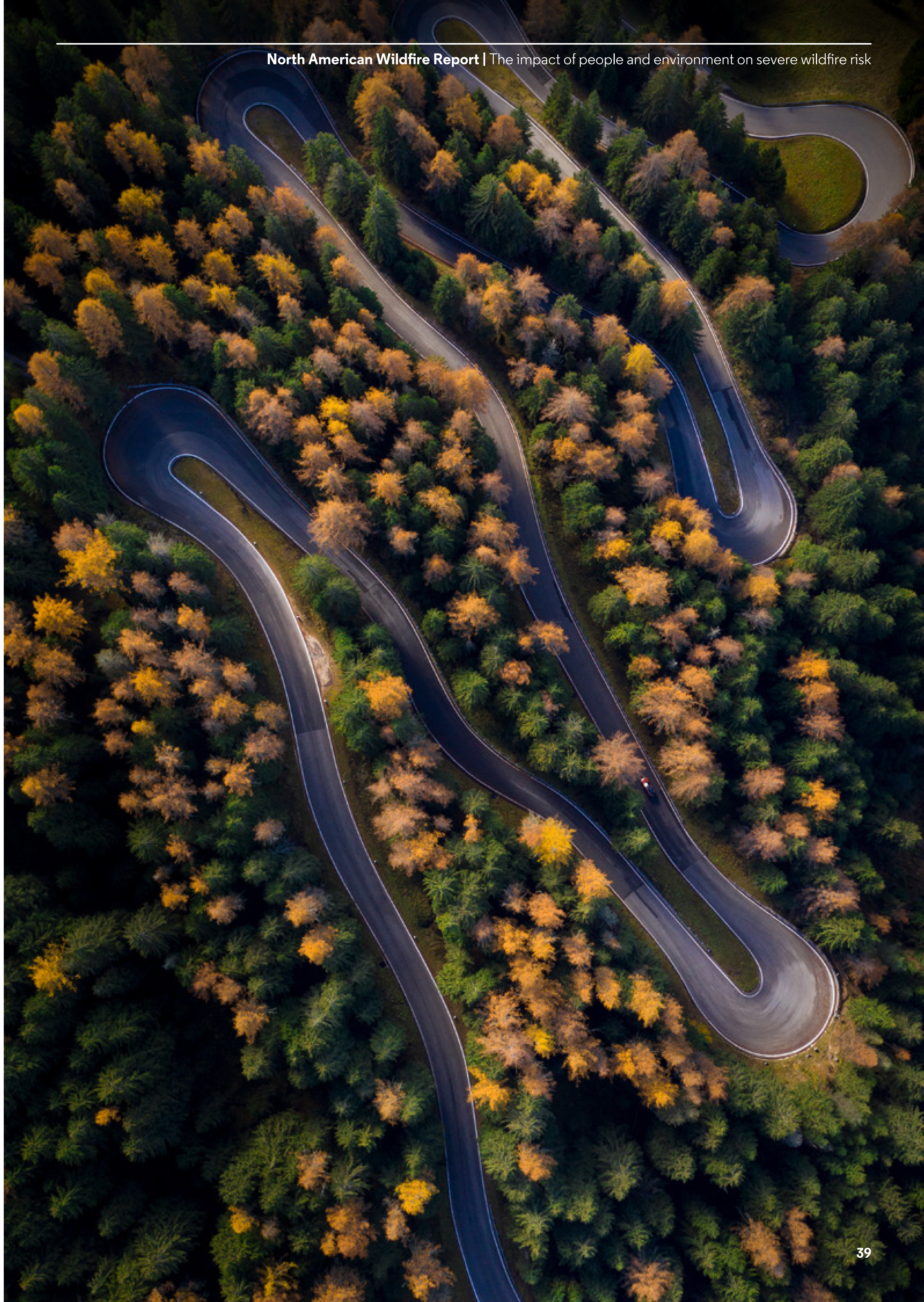
Nonetheless, these incomers are tending to move to areas which are at high risk of wildfires, meaning that when fires ignite more people are potentially affected. Particularly popular as a destination is the stretch of the mountains between Salt Lake City, Utah and Denver, Colorado.

Climate factors

- All the trends along the West Coast of the US also hold true here

People factors

- Historically the main difference between the wildfire risk in California and the Southern Rockies was the lower population density in the latter which mitigated the impact
- The main exposures in and around this region used to be ski resorts and cabins. However, we are now seeing people from California relocating here (particularly since Covid). The relocators bring their mentality and values with them. They want to live in wooden houses, in the forest, up high, with a view, and they often have more valuable possessions (likely increasing the exposures and average claims sizes). We are starting to see high net worth communities springing up in these areas. Thus, when fires start, they tend to damage and destroy increasingly valuable properties



Region Two: Alberta / British Columbia

Brief Summary: Two hotspots to watch – Okanagan Valley and Banff to Calgary Corridor

This region has many of the same climate and people factors as California. However, the population is generally quite sparse. The two "hot spots" we would call out are the Okanagan Valley (factors here are a dry, hot climate in the summer and autumn, with a wet, snowy winter and material elevation change) and the corridor between Banff and Calgary (the main factor here is katabatic winds, known locally as Chinook winds). Both regions are relatively densely populated, have high value homes (by Canadian standards) and are growing quickly.

Climate factors

- *Summers are becoming hotter and drier*
  Parts of these provinces have always been hot and dry, but climate change is increasing the likelihood of extreme temperatures. In 2021, Lytton (a small town in BC) broke the record for Canada's hottest daily high with a temperature of 49C. On that day, the town was evacuated as a wildfire spread through the area. We believe this type of extreme weather event will happen more frequently in the future.

- *Large amounts of fuel*
  Forests in British Columbia and Alberta have a long, wet growing season because of the snowfall in the mountains. This means plenty of fuel.

- *Katabatic winds*
  Chinook winds in Alberta blow down off the Rockies onto the plains.

- *Pine beetles*
  Both Alberta and British Columbia in particular have high levels of pine beetle infestation.

People factors

The “people” factors observed on the West Coast of the US hold true in this region as well:

- *Property location and type*
  People increasingly want to live in the mountains and in forested areas, often in the wildland-urban interface (area where the wilderness and human development meet). North American homes are often built of wood and the desire to have a nice view means houses are being built up into the hills.

- *Fire management leading to accumulation of fuel*
  Fire suppression techniques are similar to those used in California and this leads to a build-up of fuel. Although fire response agencies will sometimes let fires burn, as soon as they approach towns, these fires tend to be extinguished.

  Many towns have been fighting fires around their peripheries for decades. This means they haven’t allowed undergrowth to burn and there is an accumulation of dry, dead material which would not naturally occur. These accumulations tend to be close to towns and communities, which exacerbates the effects of fires when they do approach towns.

Two hotspots to watch: Okanagan Valley and Corridor from Banff to Calgary

We believe there are two regions within British Columbia and Alberta that are particularly high risk. These include:

1. Okanagan Valley

This area is hot and dry, has many high net worth dwellings, vineyards, and other high value insured assets, with steep elevation change around the towns.

2. Corridor from Banff to Calgary

This area is prone to katabatic winds. The Chinook winds blow down the Rockies and out onto the plains. This area is more densely populated than other parts of Alberta and British Columbia. It is possible that a fire similar to the Marshall Fire in Colorado (Dec 2021) could happen here. This was a grass fire that was driven by katabatic winds and was one of the most destructive fires in Colorado’s history.

Region Three: The Appalachians (including Tennessee, Kentucky, West Virginia, Pennsylvania, and New York)

Brief Summary: Climate change – especially rainfall and temperature

The Appalachian region shares many of California's pre-existing conditions for large fires. It is mountainous with significant elevation change, there are large tracts of unbroken forests with plenty of fuel and there are beetle infestations. However, we believe the major factor here will be climate change. We think the differential regional effects of climate change – especially temperature and precipitation – will drive wildfire risk across the region to varying extents.

Climate

The Appalachians have many conditions which are conducive to significant fires:

- Large tracts of unbroken forest, which means plenty of opportunity for fires to ignite and spread
- The region is mountainous, and beetle infestations are an issue. However, this is not as significant a problem as it is in California as many trees in this region are deciduous and, so, unaffected by beetles
- Although the Appalachians are lower in elevation than the Californian mountains, there is still significant elevational change and some areas are classes as special (katabatic) wind regions by FEMA
- We think that climate change, especially the differential regional effects of climate change, could be the most important factor in this region. We believe this area, which we define as running from Tennessee to Upstate New York, will see changes to patterns of rainfall and temperature going forward[41]

People factors

- The Appalachian region, which has been settled for centuries, has a greater number of exposure pockets, population centres and communities than British Columbia or Alberta. However, it is more similar to Oregon and Washington in terms of population density and distribution than California
- Peoples' residential habits and forest management practices factors (both noted above and throughout) apply here as well

41. Harris, R. Appalachia to become hotter wetter and drier in climate model with severe economic impacts. (2019, August 11) WVTF. Accessed on 3 November 2022 https://www.wvtf.org/news/2019-08-11/appalachia-to-become-hotter-wetter-and-drier-in-climate-model-with-severe-economic-impacts

Region Four: Texas

Brief overview: Californian relocators, tech migration and high net worth communities in rural areas near "flammable" natural resource extraction areas

While Texas is mostly not very mountainous, there are a number of pre-existing conditions that make it a higher fire risk region. It has a humid climate (high moisture and precipitation) with an extended growing season followed by dry winters. However, the main reason for its inclusion here is demographic.

Much like the Southern Rockies, high net worth individuals and tech companies are relocating from California to Texas. There is high population growth and construction, meaning building regulation in the wildland-urban interface has often not kept pace.

Climate factors

- Texas has a humid climate (high moisture, high precipitation) and an extended growing season
- Texas also has large expanses of grasslands
- It is often extremely hot and very windy. According to a 2021 report by the Texas State Climatologist and Texas A&M University, the average temperature and number of extreme temperature days (days over 100-degrees Fahrenheit) are likely to increase materially. The report also states that increased dryness is likely to extend the wildfire season in areas of the state where low aridity currently constrain it[42]

42. Nielsen-Gammon, J., Holman, S., Buley, A., and Jorgensen, S. (2021) Assessment of historic and future trends of extreme weather in Texas, 1900-2036. Texas A&M University Office of the Texas State Climatologist. https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update

People Factors

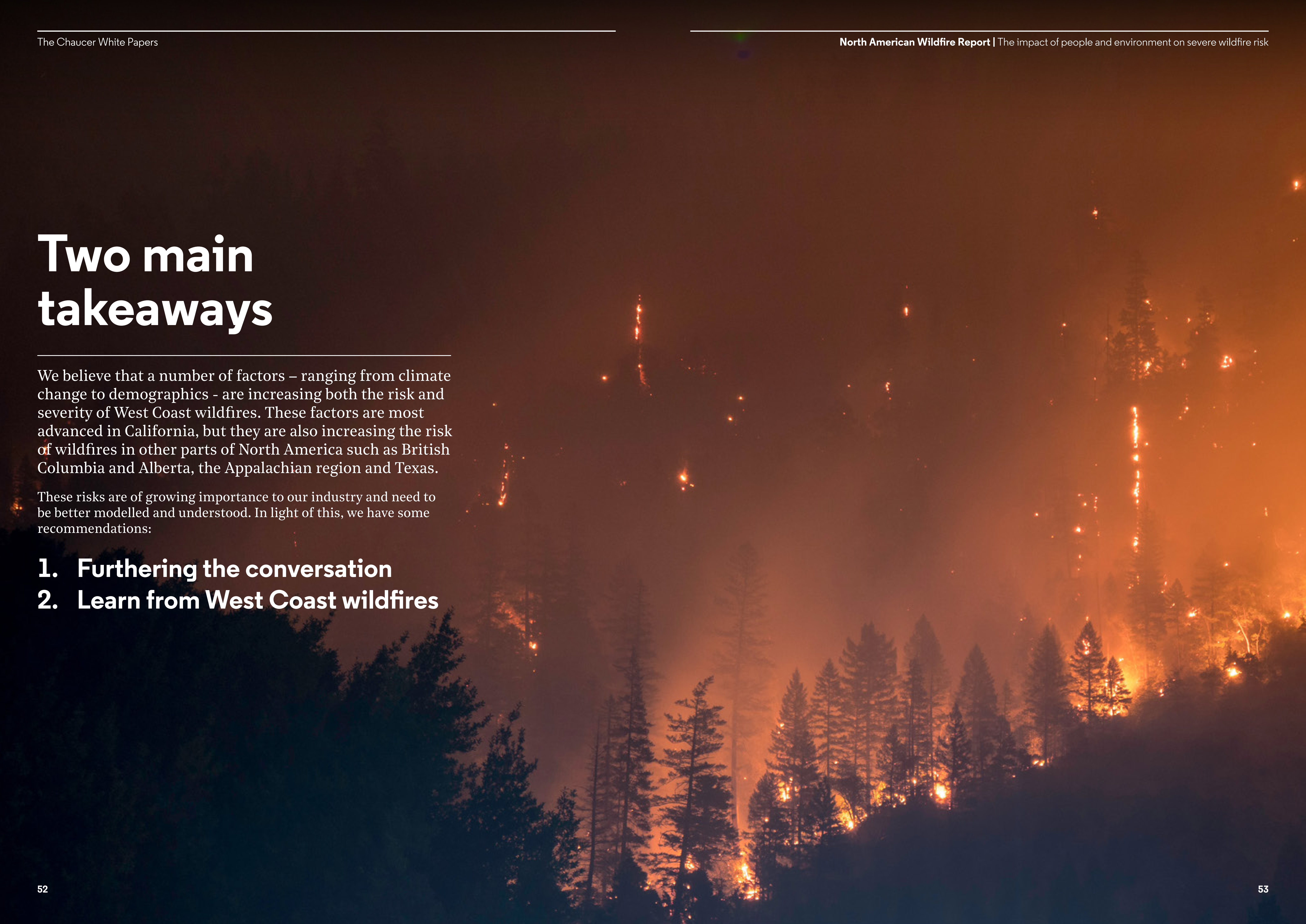
- Large numbers of tech companies and employees are relocating from California (particularly the San Francisco Bay area) to Texas. They are moving to both urban and rural areas and are bringing a West Coast mentality with them
- Rapid population growth means a construction boom. Building regulation and urban planning are often struggling to keep pace
- This is leading to high exposure growth, not just in volume (the number of properties) but also in asset values (more valuable household contents mean an increase in average claim size). Thus, we could potentially have a perfect storm of risk – more and bigger houses built in riskier areas, weak regulation and high value contents
- Finally, Texas is home to extractive industries. Many areas are close to places where fracking, or gas and oil fields are present. This means large quantities of flammable substances may be nearby, should a fire start

Lessons from Fort McMurray wildfire in Canada

The Fort McMurray wildfire was the largest catastrophic loss in Canada's history. There were a number of factors behind this.

Fort McMurray is located in a remote area of Canada where oil is extracted from tar sands. Most people who lived there flew in and out given the remote location, and the residents tended to be high net worth individuals whose household contents were far more valuable than the norm due to the large salaries paid to workers by the companies working the oil sand extraction sites nearby. This was one of the main reasons the loss was so large – individual claims were disproportionately high.

Texas has many of the same factors. Rapid growth in house numbers, high net worth incomers, flammable natural resource extraction and a "pioneer spirit" that means many people want to live in or near the wilderness. We believe Texas could be an overlooked wildfire risk.



Two main takeaways

We believe that a number of factors – ranging from climate change to demographics - are increasing both the risk and severity of West Coast wildfires. These factors are most advanced in California, but they are also increasing the risk of wildfires in other parts of North America such as British Columbia and Alberta, the Appalachian region and Texas.

These risks are of growing importance to our industry and need to be better modelled and understood. In light of this, we have some recommendations:

1. **Furthering the conversation**
2. **Learn from West Coast wildfires**

1 Furthering the conversation

This paper is intended to pose a challenge to the insurance industry, underwriters and catastrophe model vendors. These areas of wildfire risk need more attention. More needs to be asked about these risks and more research is needed.

Many catastrophe models available to insurers for North America wildfire risk do consider all or some of the factors discussed here. However, a key challenge to the market is that the models are not used to set market pricing, nor are they widely used for risk aggregation. As a result they remain relatively untested in practice. A third party assessment such as this paper can be a way to evaluate the ability of these models to estimate current and future relative risk.

We hope this paper highlights wildfire risk in terms of both the drivers and the high potential risk regions and that this keeps wildfires at the forefront of the industry's mind.

2 Learning from West Coast wildfires

As wildfire increasingly becomes an catastrophic risk, we need to be able to take the lessons from the wildfires along the West Coast of the US (especially California) and apply them quickly as new regions begin to experience material wildfire losses.

For example, some of the "innovations" that have emerged in the aftermath of these fires include new parametric products and offerings and bespoke models which use better data and advanced analytics.

We believe there is a tremendous opportunity for the industry to build our understanding and modelling of the peril that wildfires pose. Maximisation of this opportunity would require a broader application of specific data as outlined and a faster programme of change to forestry management and fire prevention methods, to keep up with demographic movements.

Regulatory change may be needed to permit more bespoke modelling solutions in the insurance industry, which utilise more recent data and are better suited to the rapidly changing environment. With more accurate, updated models, it should be possible for the industry to create more innovative forms of risk transfer that ensure a sustainable market for our insureds going forward.

Conclusion

As wildfire increasingly becomes an uninsurable peril[43], we need to be able to take the lessons from the wildfires along the West Coast of the US (especially California) and apply them quickly as new regions begin to experience material wildfire losses.

For example some of the "innovations" that have emerged in the aftermath of these fires include new parametric products and offerings and bespoke models which use better data and advanced analytics.

We believe there is a tremendous opportunity for the industry to build our understanding of the modelling of the peril that wildfires pose. Maximisation of this opportunity would require a broader application of specific data as outlined and a faster programme of change to forestry management and fire prevention methods, to keep up with demographic movements. Regulatory change may need to take place to permit bespoke modelling solutions which are better suited to the rapidly changing environment.

With more accurate updated models, it will be possible for the industry to create more innovative forms of risk transfer that ensure a sustainable market for our insureds going forward.

43 The Nature Conservancy and Willis Towers Watson Wildfire Resilience Insurance: Quantifying the Risk Reduction of Ecological Forestry with Insurance. Summary of Insights (2021) https://www.wtwco.com/-/media/wtw/insights/2021/07/wildfire-resilience-insurance-quantifying-the-risk-reduction-of-ecological-forestry.pdf?modified=20210706120957

Endnotes

Page 9

1. Dong, C., Williams, A.P., Abatzoglou, J.T., Lin, K., Okin, G., Gillespie, T., Long, D., Lin, Y., Hall, A. and MacDonald, G. (2022) The season for large fires in Southern California is projected to lengthen in a changing climate. Communications in Earth and Environment 3, 22. https://doi.org/10.1038/s43247-022-00344-6

Page 10

2,3. Dong, C., Williams, A.P., Abatzoglou, J.T., Lin, K., Okin, G., Gillespie, T., Long, D., Lin, Y., Hall, A. and MacDonald, G. (2022) The season for large fires in Southern California is projected to lengthen in a changing climate. Communications in Earth and Environment 3, 22. https://doi.org/10.1038/s43247-022-00344-6

Page 11

4. Bedsworth, L., Cayan, D., Franco, G., Fisher, L., and Ziaja, S. (2018). California's Fourth Climate Change Assessment: State Wide Summary Report. https://climateassessment.ca.gov/

5. Goss, M., Swain, D. L., Abatzoglou, J. T., Sarhadi, A., Kolden, C. A., Williams, A. P., & Diffenbaugh, N. S. (2020). Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. Environmental Research Letters, 15(9), 094016. https://doi.org/10.1088/1748-9326/ab83a7

6. Luković, J., Chiang, J. C. H., Blagojević, D., & Sekulić, A. (2021). A later onset of the rainy season in California. Geophysical Research Letters, 48, e2020GL09350. https://doi.org/10.1029/2020GL090350

7. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843

Page 13

8,10,11. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843

9. Luković, J., Chiang, J. C. H., Blagojević, D., & Sekulić, A. (2021). A later onset of the rainy season in California. Geophysical Research Letters, 48, e2020GL09350. https://doi.org/10.1029/2020GL090350

Page 14

12. Holden, Z. A., Swanson, A., Luce, C. H., Jolly, W. M., Maneta, M., Oyler, J. W. and Affleck, D. (2018). Decreasing fire season precipitation increased recent western US forest wildfire activity. Proceedings of the National Academy of Sciences, 115(36), E8349-E8357.https://doi.org/10.1073/pnas.1802316115

13. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843

Page 16

14,15. Alexander, Kurtis and Blanchard, John. "Are infamous Diablo winds responsible for recent wildfires?" The San Francisco Chronicler. 28 October 2019. Accessed 24 October 2022. https://www.sfchronicle.com/environment/article/Are-infamous-Diablo-winds-responsible-for-recent-14570132.php

Page 17

16. Li, X., Zheng, W., Pichel, W. G., Zou, C.-Z. and Clemente-Colón, P. (2007), Coastal katabatic winds imaged by SAR. Geophysical Research Letters, 34, L03804. https://doi.org/10.1029/2006GL028055

17. Potter, B. and McEvoy, D. (2021) Weather factors associated with extremely large fires and fire growth days. Earth Interactions. 25(1): 160-176. https://doi.org/10.1175/EI-D-21-0008.1.

18. Mass, C. F., Ovens, D., Conrick, R., and Saltenberger, J. (2021). The September 2020 Wildfires over the Pacific Northwest. Weather & Forecasting, 36(5), 1843–1865. https://doi.org/10.1175/WAF-D-21-0028.1

19. Kolden, C. A., & Abatzoglou, J. T. (2018). Spatial distribution of wildfires ignited under katabatic versus non-katabatic winds in Mediterranean Southern California USA. Fire, 1(2), 19. https://doi.org/10.3390/fire1020019

Page 18

20. Swain, D. L. (2021). A shorter, sharper rainy season amplifies California wildfire risk. Geophysical Research Letters, 48(5), e2021GL092843. https://doi.org/10.1029/2021GL092843

20,22. Guzman-Morales, J., & Gershunov, A. (2019). Climate change suppresses Santa Ana winds of Southern California and sharpens their seasonality. Geophysical Research Letters, 46, 2772– 2780. https://doi.org/10.1029/2018GL080261

Page 21

23. Bentz, B., Régnière, J., Fettig, C., Hansen, E., Hayes, J., Hicke, J., Kelsey, R., Negrón, J. and Seybold, S. (2010) Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects, BioScience, 60(8), 602–613, https://doi.org/10.1525/bio.2010.60.8.6

24. Meddens, A., Hicke, J., and Ferguson, C. (2012) Spatiotemporal patterns of observed bark beetle-caused tree mortality in British Columbia and the Western United States. Ecological Applications, 22(1), 1876-1891, https://doi.org/10.1890/11-1785.1

Page 22

25. Meddens, A., Hicke, J., and Ferguson, C. (2012) Spatiotemporal patterns of observed bark beetle-caused tree mortality in British Columbia and the Western United States. Ecological Applications, 22(1), 1876-1891, https://doi.org/10.1890/11-1785.1

Page 23

26. Bentz, B., Régnière, J., Fettig, C., Hansen, E., Hayes, J., Hicke, J., Kelsey, R., Negrón, J. and Seybold, S. (2010) Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects, BioScience, 60(8), 602–613, https://doi.org/10.1525/bio.2010.60.8.6

27,28,29. Fettig, C.J., Hood, S, J,. Runyon, J. B. and Stalling, C. M. (2021). Bark beetle and fire interactions in western coniferous forests: Research findings. Fire Management Today. 79(1): 14-23. https://www.firescience.gov/projects/20-1-01-14/project/20-1-01-14_FMT_2021.pdf

Page 24

30,31. Fettig, C.J., Hood, S, J,. Runyon, J. B. and Stalling, C. M. (2021). Bark beetle and fire interactions in western coniferous forests: Research findings. Fire Management Today. 79(1): 14-23. https://www.fs.fed.us/psw/publications/fettig/psw_2021_fettig006.pdf

Page 27

32. CALFIRE (2021) Fuel Reduction Guide. California Department of Forestry and Fire Protection. http://www.fire.ca.gov.

33. Keeley, J.E., Syphard, A.D. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. fire ecol 15, 24 (2019). https://doi.org/10.1186/s42408-019-0041-0

34. Johnston, J. D., Olszewski, J. H., Miller, B. A., Schmidt, M. R., Vernon, M. J., & Ellsworth, L. M. (2021). Mechanical thinning without prescribed fire moderates wildfire behaviour in an Eastern Oregon, USA ponderosa pine forest. Forest Ecology and Management, 501, 119674. https://doi.org/10.1016/j.foreco.2021.119674

Page 28

35. CALFIRE (2021) Fuel Reduction Guide. California Department of Forestry and Fire Protection. http://www.fire.ca.gov.

36. Keeley, J.E., Syphard, A.D. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. Fire Ecology. 15, 24 (2019). https://doi.org/10.1186/s42408-019-0041-0

37. Stephens, S., Collins, B., Fettig, C., Finney, M., Hoffman, C., Knapp, E., North, M., Safford, H. and Wayman, R. (2018) Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire, BioScience, 68(2), 77–88, https://doi.org/10.1093/biosci/bix146

Page 31	**37** Fire Hazard Severity Zones Maps. CALFIRE. Accessed on 3 November 2022 https://osfm.fire.ca.gov/divisions/community-wildfire-preparedness-and-mitigation/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/ 38 Moving East: California's Population Growth. California State Association of Counties. Accessed on 3 November https://www.counties.org/csac-bulletin-article/moving-east-californias-population-growth 39 De Freitas, W. The fastest population growth in the West's wildland-urban interface is in areas most vulnerable to wildfires. (2022, February 7). The Conversation.https://theconversation.com/the-fastest-population-growth-in-the-wests-wildland-urban-interface-is-in-areas-most-vulnerable-to-wildfires-173410 40 4. Rao, K., Williams, A., Diffenbaugh, N. Yebra, M. and Konings, A. (2022) Plant-water sensitivity regulates wildfire vulnerability. Nature Ecology & Evolution. 6:332-339. https://doi.org/10.1038/s41559-021-01654-
Page 45	**41.** Harris, R. Appalachia to become hotter wetter and drier in climate model with severe economic impacts. (2019, August 11) WVTF. Accessed on 3 November 2022 https://www.wvtf.org/news/2019-08-11/appalachia-to-become-hotter-wetter-and-drier-in-climate-model-with-severe-economic-impacts
Page 46	**42.** Nielsen-Gammon, J., Holman, S., Buley, A., and Jorgensen, S. (2021) Assessment of historic and future trends of extreme weather in Texas, 1900-2036. Texas A&M University Office of the Texas State Climatologist. https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update
Page 56	**43** The Nature Conservancy and Willis Towers Watson Wildfire Resilience Insurance: Quantifying the Risk Reduction of Ecological Forestry with Insurance. Summary of Insights (2021) https://www.wtwco.com/-/media/wtw/insights/2021/07/wildfire-resilience-insurance-quantifying-the-risk-reduction-of-ecological-forestry.pdf?modified=20210706120957

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