Climate and Wildfire Risk

Evidence Brief #205 - 2023

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Fire and Emergency commissions research to support its main functions:

- Reducing the likelihood of unwanted fires.
- Reducing consequences from emergencies.
- Helping build resilient communities.

Evidence Briefs summarise this research, on specific topics. They are the initial port of call for decision makers, policy makers and operational staff looking to influence fire-related outcomes.

Summary

Although wildfires are a natural part of many healthy ecosystems, they also threaten life, property, important habitats, the economy, and infrastructure. Over the last 30 years, the number of wildfires in New Zealand has risen from around 3,000 to nearly 5,000. Climate change appears to be playing a significant role in the increasing severity and length of fire seasons. This increased risk relates to:

- warmer, drier, and windier conditions,
- longer fire seasons and increased drought frequency, and
- increased frequency of thunderstorms and lightning, leading to easier ignitions.

Some of this risk might be offset by increased rainfall in some parts of the country (for example, in the south and west of the South Island). But overall, temperature, wind, and annual rainfall changes, have led to an upward trend of fire danger levels over the last 20 years.

This evidence brief canvases the extensive body of research on:

- Development and validation of fire climate measures and indicators of wildfire risk.
- Prediction of wildfire risk over short- and long-term scenarios with climate change.
- Prediction of wildfire risk at the regional level, and the importance of understanding the rural-urban interface where risks are particularly high
- Development and refinement of tools and techniques to understand New Zealand's fire climate, through the New Zealand Fire Danger Rating System (NZFDRS) and its core – the Fire Weather Index (FWI) system.

Recommendations from the research

For fire region/district managers

1. The research enables fire region/district managers to make more informed fire management decisions on fire prevention and preparedness activities and resourcing now and in the future.
2. Fire region/district managers need to understand the changing fire climate of the region, and the importance of the rural-urban interface, as there may be more extreme wildfires.
3. The Fire Weather Index codes should be used together as a system, rather than individually.

For homeowners and communities

1. The need to understand local wildfire risk when building or remodelling a home, and landscaping or designing defensible space. Follow the New Zealand Building Code and all applicable local regulations.
2. The need to prepare for each wildfire season, and make a wildfire plan.
3. Always evacuate if a wildfire threatens your home.
4. Territorial authorities and social partners should support their communities to undertake the above.

For Fire and Emergency research, policy, and practice

1. Continue to invest in the development and refinement of tools and techniques to understand New Zealand's fire climate.
2. Continue to improve the quantity and quality of weather stations.
3. Use climate change and wildfire risk knowledge in national level procurement.
4. Continue to refine the quality and predictability of software available to fire region/district managers to understand risk in their regions.

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Climate and wildfire risk

The number of very high and extreme fire danger days are increasing in some places in New Zealand

Although wildfires can be a natural part of healthy ecosystems, they also threaten life, property, important habitats, the economy, and infrastructure.1–3 Smoke from wildfires can impact human health through reduced air quality, as well as aviation activities via reduced visibility.[4] Table 1 summarises the impacts of a few of the catastrophic wildfires that have occurred in New Zealand since 2017, including at Lake Ōhau (Twizel) in October 2020 that led to $35.8 million in insurance claims and destruction of half of the township.

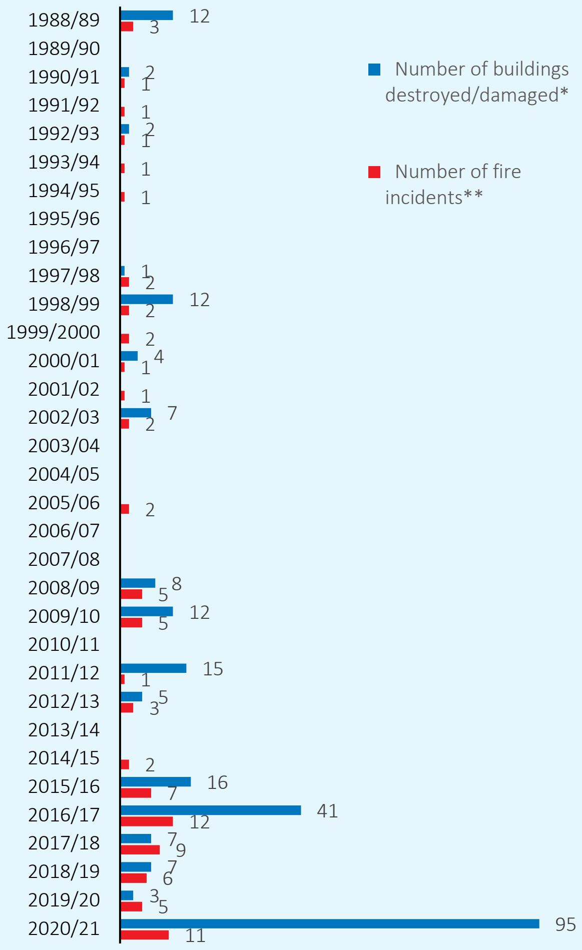
Figure 1 shows the number of buildings lost and the number of rural-urban interface fire incidents between 1988 and 2021 – a steady increase over time.

Table 1.
Major catastrophic wildfires in New Zealand since 2017

DATE	FIRE	AREA BURNED	COSTS	BUILDING LOSSES	OTHER IMPACTS
February 2017	Port Hills, Christchurch	1,661 hectares	• $7.9 million firefighting • $18.3 million insurance claims	• 9 homes destroyed and several outbuildings • 450 homes and 2,800+ people evacuated	• 1 fatality (helicopter pilot) • 400+ hectares commercial forest • Adventure Park impacted, including gondola
February 2019	Pigeon Valley, Nelson Tasman	2,316 hectares	• $12.5 million firefighting • $3.98 million insurance claims	• 1 home destroyed • 3,000+ people evacuated	• 1,949 hectares of commercial forest burnt • Forestry sector $2 million per day in lost earnings
November 2019	Deep Stream, Dunedin	4,664 hectares		• 1 shed destroyed • 1 threatened house evacuated	• 1,100 hectares conservation park burned • 60% of city water catchment area burnt
August 2020	Pūkakī Downs, Twizel	3,100 hectares	• $1.2 million firefighting	• 1 home destroyed and several outbuildings • 8 properties and 300 visitors, campers evacuated	• Wilding carbon forest burnt • 80% of scientific reserve and part of wetland conservation area burnt
October 2020	Lake Ōhau, Twizel	5,032 hectares	• $1.6 million firefighting • $35.8 million insurance claims	• 45 homes destroyed (half of all homes), 3 sheds/garage • Whole village self-evacuated	• 1,900 hectares of Department of Conservation estate and small plantation burnt

Source: Adapted from Langer et al (2021)[5]

Figure 1.
Building losses in rural-urban interface wildfires in New Zealand (1988-2021)



Source: Adapted from Langer et al (2021)[5]; Fire and Emergency
Notes: *Number of buildings includes homes as well as other outbuildings both destroyed or damaged.
**Number of fire incidents includes incidents with no house loss/damage but people evacuated or threatened.

Weather is a key component of the fire environment, and an essential element of fire behaviour and fire danger.[6] Strong winds, high temperatures, low humidity, and seasonal drought, can combine to produce dangerous fire weather situations. Evidence suggests that climate change is exacerbating these conditions, and subsequently increasing wildfire risk.[7,8] Over the last 30 years, the number of wildfires have risen from around 3,000 to nearly 5,000.[9]

In 2020/21, there were 4,588 vegetation fires.[10] The Stats NZ Wildfire risk indicator, based on research undertaken by NIWA[a], specifically measures the monthly and annual number of days of Very High or Extreme (VH+E) fire danger.[4] That indicator showed that from 1997 to 2019, VH+E fire danger days in forest or grassland increased at almost half of the 28 sites measured (Figure 2). Over the 10-year period from 2010 to 2019:[4,11]

- the highest annual average number of VH+E fire danger days per year were at Lake Tekapō (36 days), Napier (30 days), Tara Hills (27 days), and Blenheim (23 days).
- the average annual number of VH+E fire risk days across all 28 sites was highest in January and February, and lowest in June.

The indicator confirmed previous research that showed that fire climate severity was highest in North Canterbury, South Canterbury, Marlborough, Wairarapa and the eastern North Island (Hawke's Bay/Gisborne).[1,12]

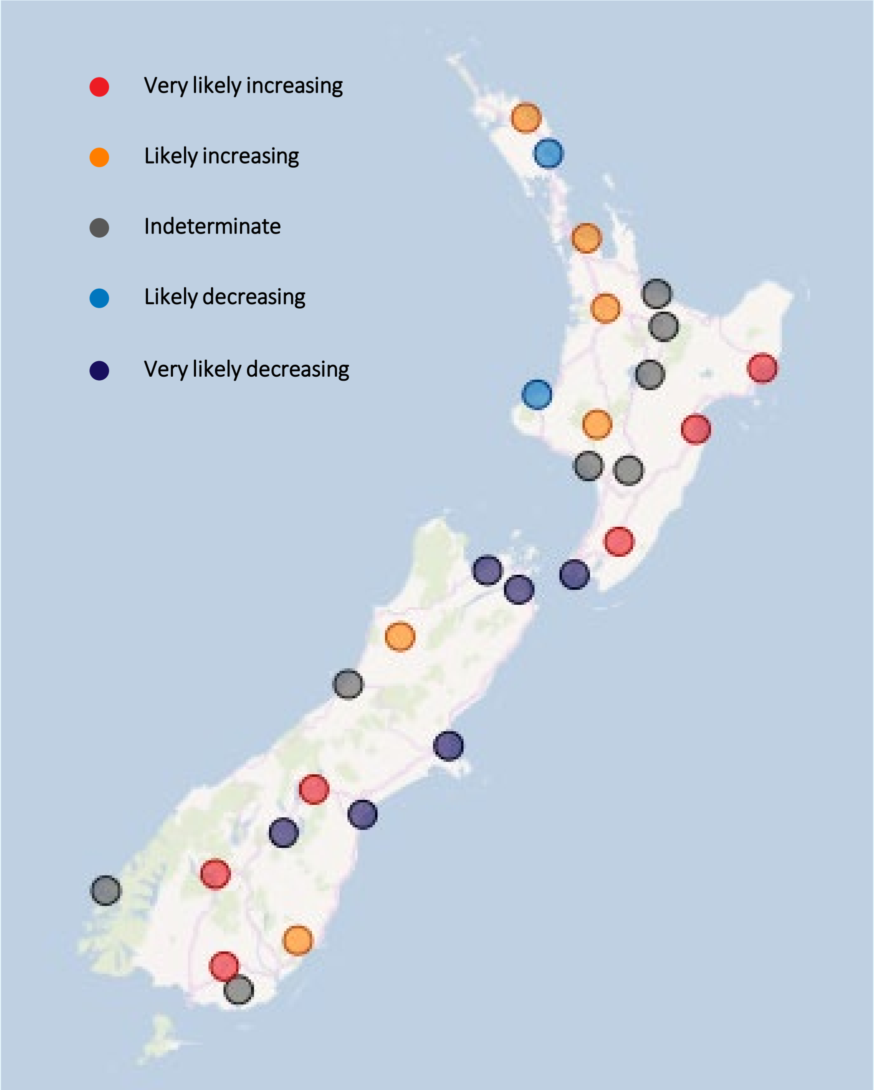
Climate change appears to be playing a significant role in the increasing severity and length of fire seasons in New Zealand.[13] This increased fire risk is due to:[7,8,14]

- Warmer, drier, and windier conditions.[2,3] Some of New Zealand's most serious fires have occurred under these extreme burning conditions.[15]
- Longer fire seasons and increased drought frequency.[16]
- Increased fuel loads, rate of fire spread, and head fire intensity.
- Increased frequency of thunderstorms and lightning, leading to easier ignitions.

Some of this risk might be offset by increased rainfall in some parts of the country (for example, in the west and south of the South Island).

a. See Macara and Sutherland (2017)[11] for research validating this indicator. The New Zealand Fire Danger Rating was used, specifically the monthly and annual number of days of Very High or Extreme (VH+E) fire danger.

Figure 2.
Wildfire risk



Source: Adapted from NIWA

Wildfire risk with climate change

Climate change scenario analyses suggest that wildfire risks will increase – in the length of the fire season and the intensity of fires – particularly in some regions.

The first such study, undertaken by Scion and NIWA using data up to December 2004, applied two Ocean-Atmosphere General Circulation Models (GCMs), the two models were CSIRO and Hadley[b] to investigate the effects of fire danger on regional climate scenarios in the 2080s.[7] The scenarios were based on those from the Intergovernmental Panel on Climate Change 3rd Assessment Report (IPCC AR3).

The two models produced different results, but they both found that New Zealand was likely to experience more severe fire weather and fire danger, especially in:

- The Bay of Plenty
- Eastern parts of the North Island
- Eastern parts of the South Island
- Central regions – Wellington and Nelson.

The 2005 study was rerun and extended in 2010, with a more complete set of data and using updated scenarios from the IPCC 4th Assessment Report.[14,17] The improved estimates found changes to be far greater than those in the 2005 study, but the results from the 16 GCMs used showed more variation. The models suggested that fire danger would likely increase more rapidly to the 2040s, but then stabilise or decrease by the 2090s. The study concluded that the areas most likely to increase from current levels were:

- East and south of the South Island, especially coastal Otago, Marlborough, and southern-eastern Southland
- Southwest of the North Island (particularly around Whanganui).

Unlike the previous study, eastern areas of the North Island – like Gisborne – and eastern areas of the South Island – like Christchurch – did not show significantly increased fire potential above current levels (which are already relatively high).[14]

The most recent extension of this body of research, undertaken in 2021 (using IPCC 5th Assessment Report scenarios), with more of a focus on the rural-urban interface, finds that average fire risk will increase, both in the length of fire seasons and the intensity of fires, until at least 2050, regardless of climate mitigation efforts.[5,18]

Most significantly, the analysis found that conditions that led to the 2019/20 “Black-Summer” fires in Australia will occur in New Zealand every 3-20 years in areas of the:[5,18]

- Mackenzie Country,
- Central Otago, and
- Marlborough.

This has significant fire risk implications for carbon sequestration and the forestry industry economy, as well as other land uses.

b. Global model outputs were downscaled using a statistical technique developed specifically for New Zealand by NIWA, to recreate regional daily fire weather and fire danger records.

Wildfire risk with climate change

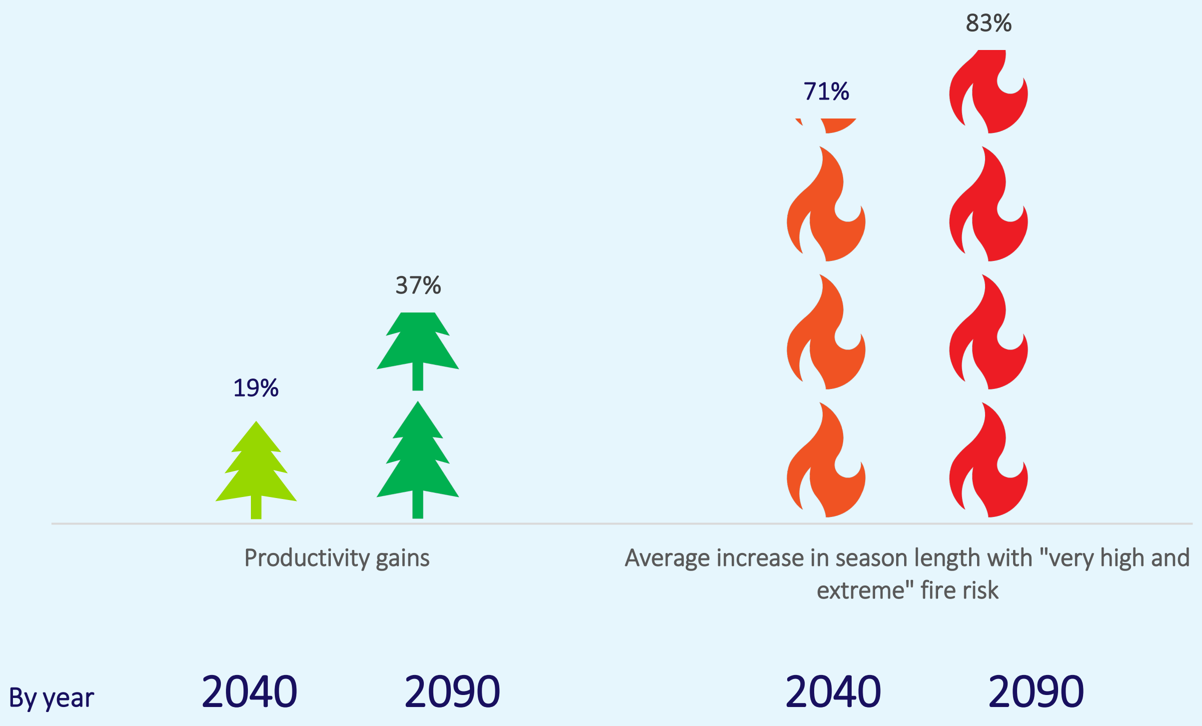
Climate change is projected to lead to productivity gains for plantation forests, but also significant climatic fire risk.

A 2018 analysis predicted climate change impacts specifically on plantation forests.[19] Taking into account:

- climate change projections (from 12 of the GCMs in the IPPCC 4th Assessment Report),
- modelled forest productivity,
- wind damage,
- fire risk, and
- pest and disease damage (distribution of pests and geographic source of future pests, damage from tree pathogens, damage from tree-feeding insects, competition with weeds).

It was found that productivity gains from increasing CO_2 would average 19% by 2040 and 37% by 2090. But the trees would become taller and more slender with substantially increased wind risk. The average season length with VH+E climatic fire risk increased by 71% up to 2040 and by 83% to 2090 (Figure 3).

Figure 3.
Plantation forests: productivity gains and increased fire risk to 2040 and 2090



Source: Adapted from Watt et al. (2019)[19]

New Zealand's fire climate

In New Zealand, fire region/district managers use the Fire Weather Index (FWI) System to monitor daily and seasonal changes in fire danger conditions. The FWI System is based on weather inputs (air temperature, relative humidity, wind speed, daily rainfall) and these are converted into numerical ratings of relative ignition potential and fire behaviour based solely on weather data (Table 2).[16]

The FWI System forms the core of the New Zealand Fire Danger Rating System (NZFDRS), as seen on roadside fire danger signs.[c,d] The NZFDRS was developed as an aid to support fire management decision-making, such as setting fire season status and restrictions, fire permit issue, preparedness planning, prescribed burning, and notifying the public of prevailing fire danger.[6]

In 1992, historical climate data for 20 weather station locations were obtained from the MetService to calculate the daily components of the FWI System and enable a regional assessment of fire dangers.[15] The analysis undertaken identified that the fire climates of many parts of the country were much more severe than previously recognised (for example, Dunedin and Wellington), providing critical information for fire region/district managers.

With establishment of a specific network of fire weather monitoring stations across the country in the mid-1990s, the study was extended and improved in 2003, accounting for 127 stations with data summarised by month, fire season, and year.[8,20] The geographic regions with the most severe fire climates were found to be Marlborough and Canterbury.[6,20]

The climatology analysis was again replicated and extended in 2011 using the longer observation records.[1,21] Under that study the regions with the highest fire climate severity values were:

- inland South Island (the Mackenzie Basin and Central Otago)
- Marlborough
- Canterbury
- eastern North Island (Hawkes Bay and Gisborne)
- areas of elevated values were also present in the Wairarapa and Northland.

Table 2.
Fire Weather Index (FWI) System outputs

INDICES	DEFINITION
Fine Fuel Moisture Code (FFMC)	A numerical rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and flammability of fine fuel.
Duff Moisture Code (DMC)	A numerical rating of the moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in duff layers of moderate depth and medium-sized woody material.
Drought Code (DC)	A numerical rating of the moisture content of deep, compact, organic layers. This code is a useful indicator of seasonal drought effects on forest fuels, and the amount of smouldering expected in deep duff layers and large logs.
Initial Spread Index (ISI)	A numerical rating of the expected rate of fire spread. It combines the effects of wind and the Fine Fuel Moisture Code on rate of spread without the influence of variable quantities of fuel.
Buildup Index (BUI)	A numerical rating of the total amount of fuel available for combustion that combines the Duff Moisture Code and the Drought Code.
Fire Weather Index (FWI)	A numerical rating of fire intensity that combines the Initial Spread Index and the Buildup Index.
Daily Severity Rating (DSR)	A parameter calculated from the Fire Weather Index that estimates the severity of the fire weather for each day. This rating reflects potential fire intensity, control difficulty, and the amount of work required to suppress a fire. When averaged or accumulated, it also allows comparison of the severity of fire weather from one year to another.

Source: Briggs, Price & Pearce (2005)[2]

c. NZFDRS categorises fire behaviour potential associated with the FWI conditions into fire danger classes (Low, Moderate, High, Very High and Extreme).

d. See the 2001 Landcare Research study[3] and the 2005 Landcare Research and Scion study[2] for further explanation of how high-resolution, spatially explicit data layers related to fuel moisture codes and fire behaviour indices have been developed and refined for the FWI. .

The lowest fire climate severity values were found in:

- the South Island's West Coast and Fiordland
- Southland
- west of the North Island (Taranaki)
- central North Island (inland Manawatu-Whanganui).

Climatologies for many of the stations have been updated (to July 2021), and summaries of long-term averages and extremes (min/max) of weather and fire danger ratings produced for 100 stations.

All the codes and indices of the FWI System need to be used together in fire management decision making.

A study in 2009 sought to address fire managers' concerns that the values of the Drought Code (DC) component of the FWI System were increasing over time in New Zealand, due to calculation issues – a lack of annual re-setting – or possibly climate change.[16] Analysis identified a mix of both increasing and decreasing trends, although few were statistically significant. It is likely that the changes in DC values are related to other factors, such as the time periods of data available and rainfall variability associated with interannual and decadal climate cycles.

The research, importantly, highlighted that fire managers should not use the DC in isolation, but use all the codes and indices within the FWI System to guide fire management decision-making as each indicates different aspects of fire potential (see Table 2).[16]

New Zealand's climate also varies by natural cycles: El Niño-Southern Oscillation and Interdecadal Pacific Oscillation.

The El Niño-Southern Oscillation (ENSO) is a major driver of New Zealand's climate, influencing ocean temperatures and rainfall, air temperature and wind patterns. It has two main phases – El Niño and La Niña, as well as a Neutral phase.

El Niño events occur irregularly, about 3 to 7 years apart, typically becoming established early in the fire season (May-October) then diminishing later in summer (February to April). In El Niño years, New Zealand tends to experience stronger and/or more frequent west to southwest winds.[22]

La Niña events bring roughly the opposite changes, with weaker westerly winds occurring in summer and more northerly quarter winds at other times. La Niña episodes usually intensify later in the season (October-January).

The Interdecadal Pacific Oscillation (IPO) is another Pacific-wide natural fluctuation in the climate, which causes abrupt shifts in ocean and atmosphere circulation patterns that persist for decades. There are two phases, positive and negative:

- The positive phase produces more westerly quarter winds over the country, with generally wetter conditions in the west and south.
- In the negative phase, with weaker westerlies over the country, more easterlies and north easterlies occur over northern New Zealand, with increased tropical disturbances.

A study on the effects of these climate variability cycles on fire danger found that they will both reinforce, or offset, the longer-term trends of more severe fire weather and fire danger expected because of climate change.[22] This was particularly so for the Bay of Plenty and in the east of the North Island and South Island. While the study identified some general trends, El Niño and La Niña events evolve differently so that averaging across years exhibiting similar phases has limited value. It was also highlighted that other shorter duration climate factors, such as the Southern Annular Mode (SAM) that influences week-to week weather, have significant influence on seasonal fire danger.

The trend towards increasing fire risk levels may not yet be apparent.

A recent study sought to understand whether a change in the availability of fuel for combustion had taken place between the periods pre-2000 and 2000 to 2020, and if fire risk was increasing with climate change.[13] Data on three components within the FWI System were examined: the Build Up Index (BUI), Drought Code (DC) and Initial Spread Index (ISI) (see Table 2 for a description of these components).

The study found that more stations showed decreases in fire dangers for the period since 2000 compared to the period prior to 2000. It is suggested that climate variability is changing wind patterns and increasing annual rainfall, thereby decreasing fuel availability to burn.[13]

As with the previous Drought Code and climate variability studies,[15,12] the researchers concluded that fire danger trends observed to date have been driven more by changes from short- to medium-term climate cycles than longer-term global warming. They suggested that the average annual frequency of higher fire danger levels across New Zealand may not increase as dramatically over the next 20 to 40 years as predicted by climate change studies, barring a major shift in current weather patterns.

There has been an increasing sophistication of measurement and prediction tools and techniques to measure wildfire risks.

Other than minor improvements and refinements to the FWI System and NZFDRS, the network of weather stations has also expanded greatly over the last 40 years. The present weather station network now comprises over 300 fire Remote Automatic Weather Stations (RAWS), with Fire and Emergency, forestry, and council stations supplemented with observations from MetService and NIWA stations. An assessment of the quality of the weather data collected and the geographical spread of the network in 2005 recommended:[12]

1. Upgrading or replacement of stations in the current fire RAWS network which have poor data records.
2. Removing redundant stations, and reassessing the total number of stations and potential sites for the future.
3. Continuing to supplement fire RAWS data with data from MetService (and NIWA) stations.
4. Providing guidance on the use of data substitutes to fill missing observations.
5. Providing guidance on the optimum choice of interpolation methods and order of interpolation for mapping of fire danger ratings.

These findings regarding the fire weather station network still remain valid today, with data quality and consistency in observation sites being critical for producing the long-term records needed to support the types of fire climatology analyses described here.

Prediction of fire danger

Fire danger levels can be predicted out to 7 to 10 days, to several months.

In addition to monitoring of current FWI conditions, fire danger levels can be predicted weeks to months in advance. Studies by MetService, NIWA and Scion developed and tested methods that are now routinely used to provide fire managers with short- and longer-term fire weather forecasts and fire danger outlooks.

Out 7 – 10 days[23,24]

Pattern recognition techniques were used which applied weather forecasts from ensemble prediction systems to observation data from 137 sites in New Zealand to forecast FWI codes and indices.[23]

Out 14 – 28 days[25,f]

Development of methods for forward prediction of severe fire weather, using predictions of the likely range of temperature and rainfall to forecast fuel moisture codes and fire behaviour indices contained within the FWI System module of the NZFDRS, for the 2 to 4-week period.

There was significant difference in the behaviour of fire risk between Northland and Canterbury. Temperature was the dominant factor for fire danger and weather severity for Canterbury, while low moisture was a more important factor for Northland.

The forecasts had significant predictive ability out to day-10. The researchers noted that fire managers may also find a chart that showed the spatial variation of Weekly Severity Rating at day-14 useful.[23]

The method was later prototyped and delivered via the MetService's MetConnect web application, which was already in use by fire managers providing hourly fire dangers. During the trial period in 2006, fire managers indicated that the 10-day forecasts of fire weather were helpful in providing advanced notice of potentially dangerous environmental conditions, and the visualisation of the mapping.[24]

This approach was also subsequently adopted by NIWA in their Ecoconnect Fire Weather System which provides forecasts of hourly fire dangers out 72 hours and daily (3-hourly) fire danger for the next 6 days via their desktop application and fire weather website.

These methods are now used alongside the longer-range 3-month forecasts to assist in producing seasonal outlooks.

Out several months[26,27]

For the period 1999 to March 2004, 16 1-month forecasts and 15 3-month forecasts were validated.[26]

- Across all fire regions, there was a 49% success rate for 1-month out, and 37% success rate 3-months out. Once "one-off misses" are removed, success rates increased to 83% and 75%, respectively.
- There was more success in predicting which areas had elevated fire danger, than prediction of fire severity level (fire danger class) for specific locations.
- The approach was used to develop a process for preparing 3-month fire climate outlooks which continue to be produced over the fire season.

Trends in the Cumulative Daily Severity Rating (CDSR) were also modelled using a parametric curve fitting method. The method was successful in modelling overall fire season severity outcome, as well as predicting seasonal severity 1-2 months ahead.[27]

- A graphing tool was developed to enable further development and testing of this methodology.
- This was later developed into a tool for tracking trends in seasonal fire danger and comparing with previous seasons.

e. Based on canonical correlation analysis (CCA).
f. The forecast data was from the US National Centers for Environmental Prediction's (NCEP) ensemble prediction system. Predictions may be improved using data from the 51-member European Centre for Medium Range Forecasting (ECMWF) ensemble.

A wide body of research has canvassed climate predictors of wildfire severity at the regional level.

Pulling together the body of research on climate and wildfire, and the evolution of analysis techniques, NIWA undertook a three-year programme of research on the investigation of climatic factors that give rise to high seasonal and monthly severe fire risk in different parts of New Zealand.[28–32] The first study included relationships between monthly weather patterns and indices of regional climate (zonal winds, Southern Oscillation Index, sea-surface temperature) to monthly and seasonal severity ratings for 21 climate stations to the year 2000.[28] The study confirmed that the high fire season typically occurs between the months of October to April.

Based on fire severity ratings and statistical techniques, 15 fire regions were identified for New Zealand – 7 in the North Island, 7 in the South Island, and one that spans parts of both islands.[29]

Subsequent analyses then went on to investigate in more detail the predictors of fire season severity in each of the different regions of the country[32-34], which were then used to aid production of the fire season outlooks mentioned above.[25]

There are number of high risk rural-urban interface areas across New Zealand.

A method has been developed for identifying the rural-urban interface (RUI) – areas where houses and other urban development are adjacent to or intermixed with flammable rural vegetation.[5,33]

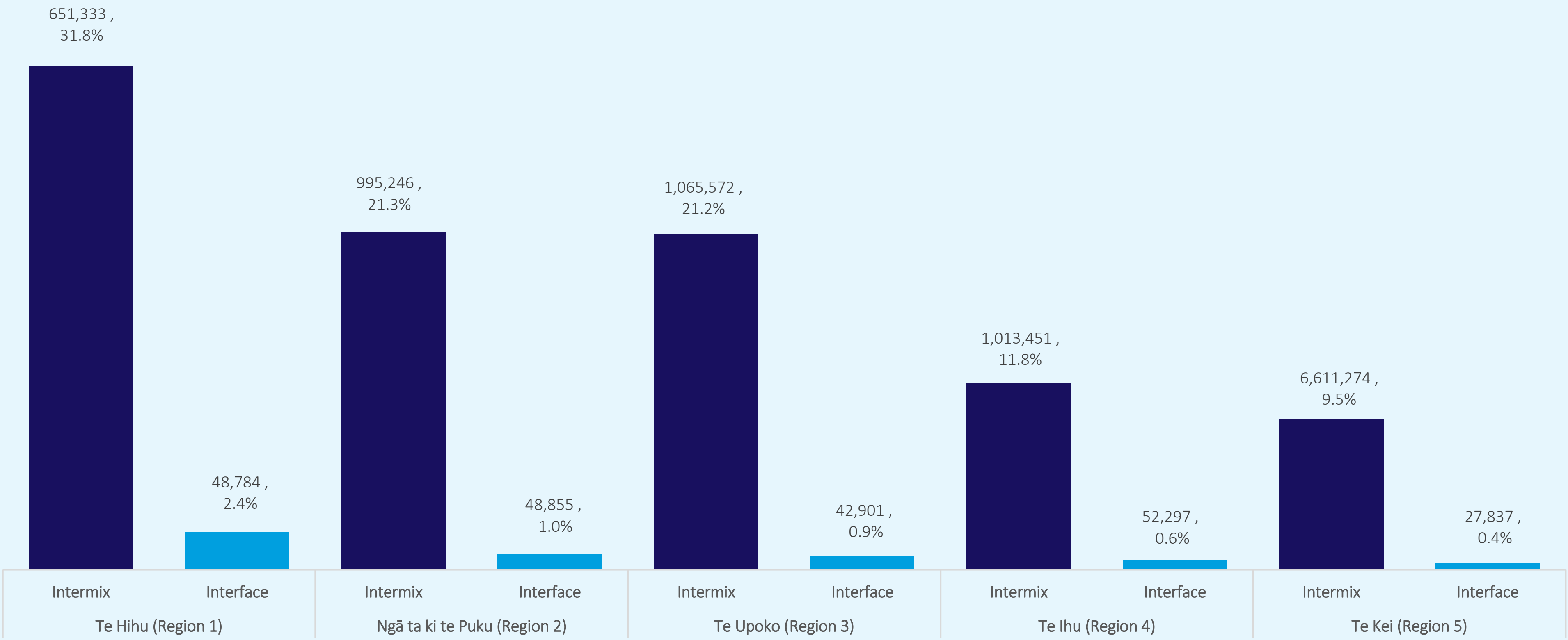
Exploratory mapping of this RUI and identification of at-risk communities finds that nearly 17% of New Zealand has the greatest risk from wildfire.[33] Of this area, 0.8% is high density and 16.1% is less densely populated. Most of the high-risk areas are in the north of the North Island (Te Hiku), and the least are in the south of the South Island (Te Kei) (Figure 4).

Results from the latest climate change study[5],18 were overlain over the mapped RUI.33 For Northern Wānaka/Albert Town in Central Otago which was used as a case study, the analysis revealed an average 32% increase in fire season length was expected for that area by 2095.

g. Principal components analysis (PCA) and cluster analysis.

Figure 4.

Indicative* percentage of total area (%) and area (hectares) of intermix and interface within Fire and Emergency fire regions



Source: Adapted from Langer et al (2021)[5]

Notes: The RUI is defined as having two components. The "intermix" is where there are houses and lifestyle properties scattered amongst vegetation. The "interface" is where there is dense development directly abutting vegetation.

* These figures should be treated as interim, due to the need for validation to ensure accuracy and currency.

While this study indicates potential increases in "average" fire behaviour potential with climate change, the current occurrence of extreme fire weather days should not be ignored.

For example, the study also found that conditions that led to the devastating 'Black Summer' fires in Australia during 2019/20 already occasionally occur in New Zealand, but could become much more frequent with climate change, occurring every 3-20 years for areas of the Mackenzie Basin, Central Otago and Marlborough. The highest risk areas have return frequencies of less than once every five years, and are found in the Mackenzie Basin and Central Otago regions (Figure 5).[5,33]

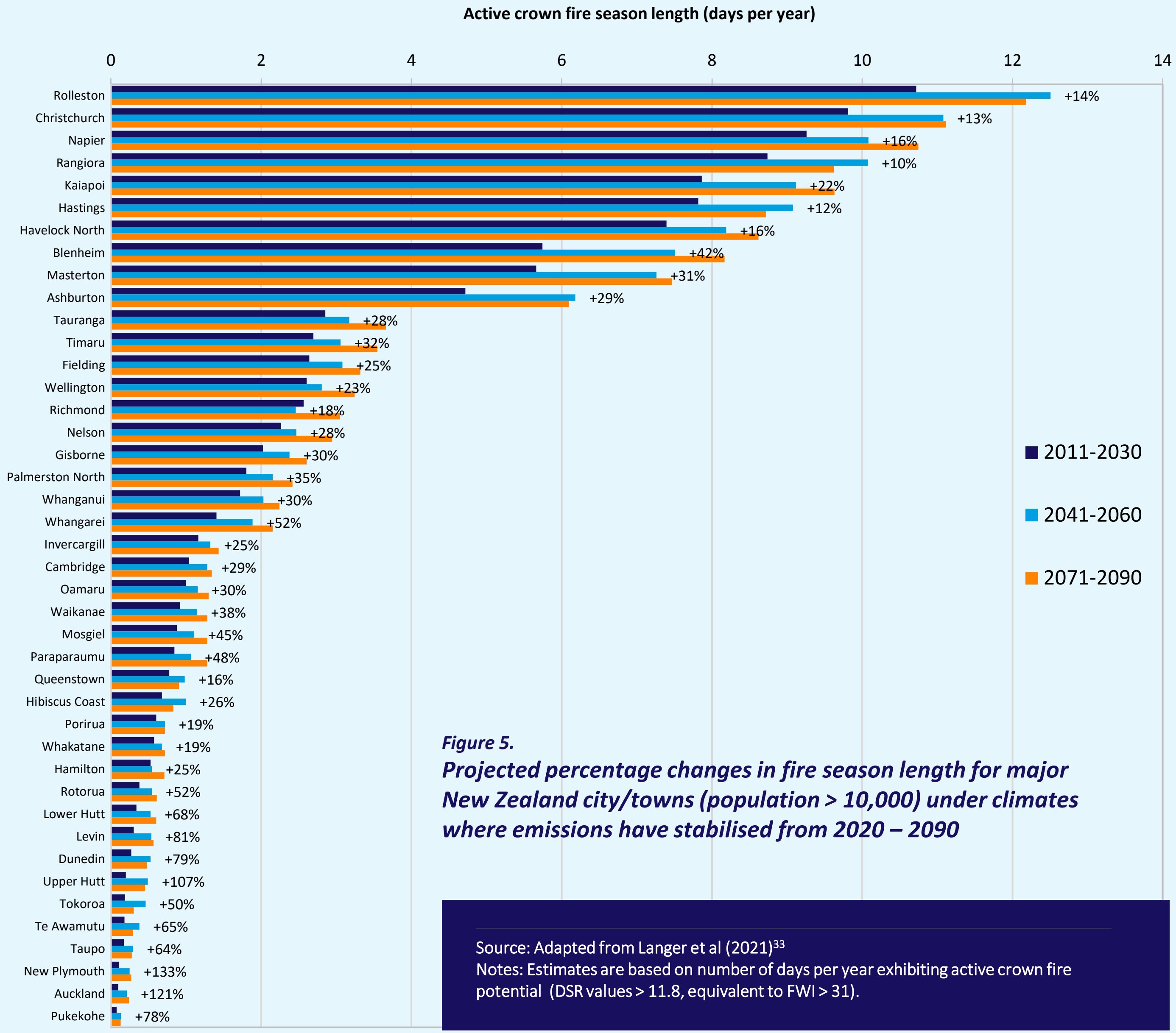


Figure 5.

Projected percentage changes in fire season length for major New Zealand city/towns (population > 10,000) under climates where emissions have stabilised from 2020 – 2090

Source: Adapted from Langer et al (2021)[33]
Notes: Estimates are based on number of days per year exhibiting active crown fire potential (DSR values > 11.8, equivalent to FWI > 31).

Recommendations and implications from the research

Implications for fire region and district managers

The research to map the rural-urban interface looked at which at-risk areas of the country could be most affected by climate change. Using a rank-based description of potential fire behaviour severity (see Table 3 for rank definitions), this showed that a new wildfire climate is emerging:[5,18]

- Much of the North Island will experience an increase in Rank 1 and 2 conditions, where pine-forest leaf-litter transitions into being flammable.
- Rank 1 and 2 emergence in Southland, Tasman, and Nelson.
- Isolated pockets of Ranks 2 and 3 emergence on the East Coast and Waikato.
- Rank 2 conditions emerge in the southern parts of the North Island.
- Ranks 3 and 4 emerging for Palmerston North and surrounds.
- Ranks 5 and 6 emerging in parts of the Wairarapa, including around Featherston and Greytown, indicating potential for extremely vigorous surface fires or crown fires [h], that may be difficult or impossible to control.
- Rank 6 emergence in large parts of Marlborough, Canterbury, and Otago, and not limited to just remote rural areas. Rank 6 emergence is predicted in Christchurch, Selwyn, Mackenzie, Waitaki, Central Otago, and Queenstown-Lakes.
- It is important to understand where the areas of most at-risk rural-urban interface (RUI) areas are located, which includes considering the effects of fuel types (fuel loads and flammability) and terrain (slope and aspect), as well as climate.[5,33]

Individual fire stations may find increased callouts to small local wildfires that will generally be easily containable. However, some may also experience increasing involvement in fighting extreme wildfires as part of larger regional operations.

Fire managers could expect longer fire seasons in some parts of the country, increased drought frequency, an increased number of fires and greater areas burned, and increased fire suppression costs and damages.[14]

h. A crown fire is a forest fire that spreads from treetop to treetop, often at great speed and well in advance of the fire on the ground.

Recommendations and implications from the research

Table 3.
Fire behaviour severity rank classes

RANK	FIRE BEHAVIOUR AND CHARACTERISTICS	REPRESENTATION
1	Smouldering ground fire • No open flame • White smoke • Slow, creeping, rate of fire spread	
2	Low-level surface fire • Visible, open flame • Unorganised or inconsistent flame front • A slow rate of spread	
3	Moderately vigorous surface fires • Organised flame front – fire progressing in an organised manner • Occasional candling may be observed along the perimeter and/or within the fire • Moderate rate of spread	
4	Highly vigorous surface fire with torching, or passive crown fire • Organised surface flame front • A moderate or fast rate of spread on the ground • Short aerial bursts through the forest canopy • Short-range spotting	
5	Extremely vigorous surface fire or active crown fire • Black to copper smoke • Organised crown fire front • Moderate to long-range spotting and independent spot fire growth	
6	A blow-up or conflagration; extreme and aggressive fire behaviour • Organised crown fire front • Long-range spotting and independent spot fire growth • Possible fireballs and whirls • Violent fire behaviour probable • A dominant smoke column may develop which influences fire behaviour	

Source: British Columbia Wildfire Service (2022)[34]

Recommendations and implications from the research

Implications for fire region and district managers

1 The research enables fire region and district managers to make more informed fire management decisions on fire prevention and preparedness activities and resourcing now and in the future.

2 Fire region and district managers need to understand the changing fire climate of the region, and the importance of the rural-urban interface, as there may be more extreme wildfires.

3 The Fire Weather Index codes should be used together as a system, rather than individually.

Recommendations and implications from the research

Implications for homeowners and communities

A case study was undertaken in northern Wānaka/Albert Town in Central Otago.[5] It has extreme wildfire risk and rapid housing development, and Fire and Emergency wanted to understand wildfire risk perceptions and preparations, and what interventions could be undertaken to improve wildfire preparations. The town's wildfire risk is due to the township being built on steep slopes, mostly facing prevailing north-westerly winds, few evacuation routes, homes with wildfire susceptible designs and materials, and highly flammable vegetation nearby (kānuka).

There was high fire awareness and anxiety amongst permanent residents, particularly due to the wildfire in November 2020 which destroyed 48 houses (half the village) at Lake Ōhau (70 km away). However, most residents only became aware of the extreme wildfire risk after purchasing or building their homes.

Collation of mitigation recommendations for households and communities from over 120 national and international publications sorts the recommendations into five broad situational categories:[5]

- Building or remodelling a home
- Landscaping or designing defensible space
- Preparing for each wildfire season
- Making a wildfire plan
- When a wildfire occurs.

Territorial authorities, iwi, and hapū need to work with residents to raise awareness and knowledge of wildfire risk and preparedness, particularly in high RUI areas.[5] This should include communicating:

- The principles of how wildfires spread and what factors affect the rate and direction of spread
- The limits of firefighting capacity and capability against fires under different weather conditions and fire intensities
- What to consider when making an evacuation plan, including information about the speed of wildfire spread, likelihood of traffic congestion, and difficulty of driving through smoke.

Implications for homeowners and communities

1 The need to understand local wildfire risk when building or remodelling a home, and landscaping or designing defensible space. Follow the New Zealand Building Code and all applicable local regulations.

2 The need to prepare for each wildfire season, and make a wildfire plan.

3 Always evacuate if a wildfire threatens your home.

Recommendations and implications from the research

Implications for Fire and Emergency research, policy, and practice

The body of research on climate and wildfire suggests a number of matters to consider for future research:

- Development and refinement of tools and techniques to understand New Zealand's fire climate, through the New Zealand Fire Danger Rating System (NZFDRS) and its core – the Fire Weather Index (FWI) system.
- The number, location, maintenance, and upgrading, of the weather stations from which data is gathered is key to the quality of the overall system.
- Continuing to support research to better understand likely future trends in wildfire risk.

Additionally, the findings led to recommendations for policy and practice, including:

- Using climate change and wildfire risk knowledge in determining locations of fire stations and national level fire-fighting procurement, including off-road "rural" fire response vehicles and air assets.[5,18]
- Continuing to refine the quality and predictability of software available to fire region/district managers to understand wildfire risk in their regions.

Implications for Fire and Emergency research, policy, and practice

1. Continue to invest in the development and refinement of tools and techniques to understand New Zealand's fire climate.
2. Continue to improve the quantity and quality of weather stations.
3. Use climate change and wildfire risk knowledge in national level procurement.
4. Continue to refine the quality and predictability of software available to fire region/district managers to understand risk in their regions.

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