Fire weather and climate of New Zealand*

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Abstract

Each year in New Zealand, seasonal weather conditions contribute to elevated fire dangers and therefore an increased risk of wildfires in most parts of the country. Weather is a key component of the fire environment, and an essential element of fire behaviour and fire danger. In particular, strong winds, high temperatures, low humidity and seasonal drought can combine to produce dangerous fire weather situations. To effectively manage this risk, an appreciation of the severity of fire weather and fire danger conditions is essential. A database has been developed of long-term daily fire weather and fire danger records from a network of more than 170 weather stations located across the country. The fire weather monitoring network comprises a mix of stations from the Meteorological Service of New Zealand (MetService), National Institute of Water and Atmospheric Research (NIWA) and Rural Fire Authorities. This database has formed the basis for a series of analyses comparing the severity of fire climates in different parts of the country, predicting the severity of fire seasons, and for projecting the likely effects of climate change on future fire dangers. This paper gives a brief overview of research undertaken to describe and predict New Zealand's fire climate.

Background

The New Zealand fire danger rating system

The New Zealand Fire Danger Rating System (NZFDRS) has been 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. The NZFDRS (Figure 1a) analyses fixed and variable fire environment factors (weather, fuels and topography) that influence ease of ignition, rate of fire spread and intensity. The system is based on the Canadian Forest Fire Danger Rating System that was introduced in New Zealand in 1980. New Zealand's adoption and ongoing adaptation of the Canadian fire danger system is described by Fogarty *et al*. (1998) and Anderson (2005, 2006).

At the core of the NZFDRS, the Fire Weather Index (FWI) System (Figure 1b) provides numerical ratings of relative ignition potential and fire behaviour, based solely on weather data (Van Wagner 1987, Anderson 2005). Observations of temperature, relative humidity, wind speed and 24-hour accumulated rainfall are collected daily by a network of automatic weather stations. These values are used to compute the fuel moisture codes and fire behaviour indices that make up the FWI System.

Fire weather monitoring

An automated Fire Weather Monitoring System (FWSYS) that utilises GIS and database technology was implemented by the National Rural Fire Authority (NRFA) in 2002. Within FWSYS, current fire weather, fire danger and fire behaviour potential are updated daily based on information collected from the network of remote automatic weather stations. Daily and hourly data from each station are downloaded and archived within the NRFA's fire weather database and distributed via their website (www.nrfa.fire.org.nz). The archiving of historical records of

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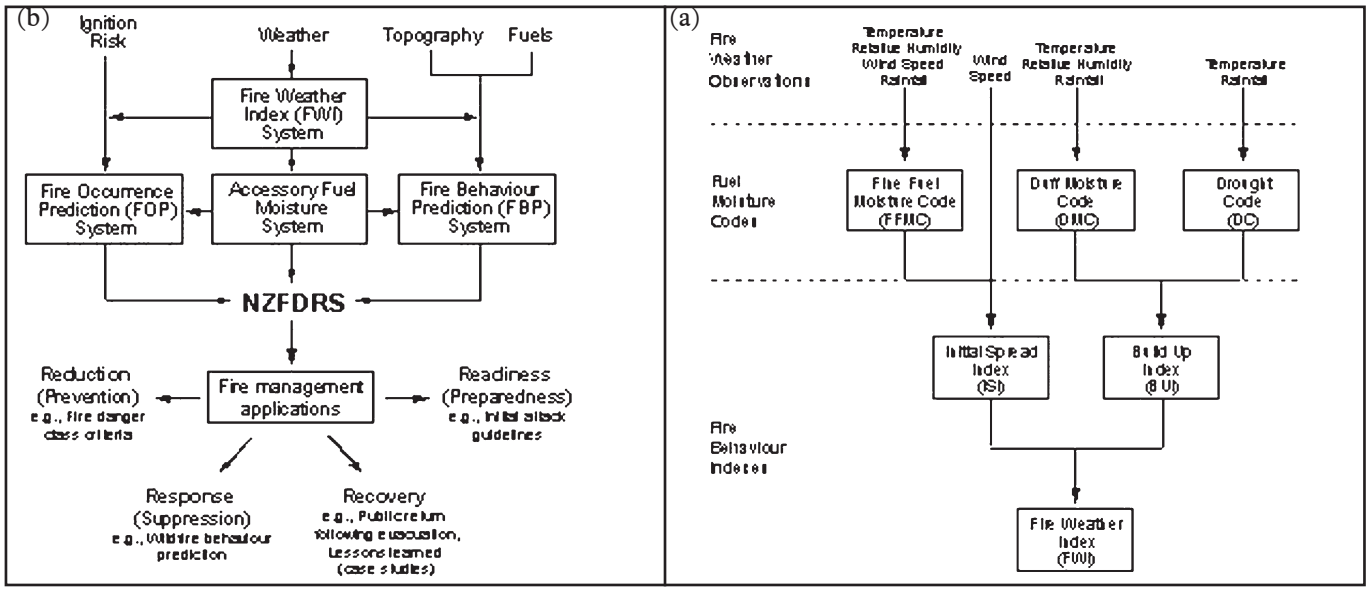

Figure 1. Structure diagrams for (a) the New Zealand Fire Danger Rating System (NZFDRS), illustrating the linkage to fire management actions (after Fogarty et al. *1998); and (b) the Fire Weather Index (FWI) System (after Anon. 1993).*

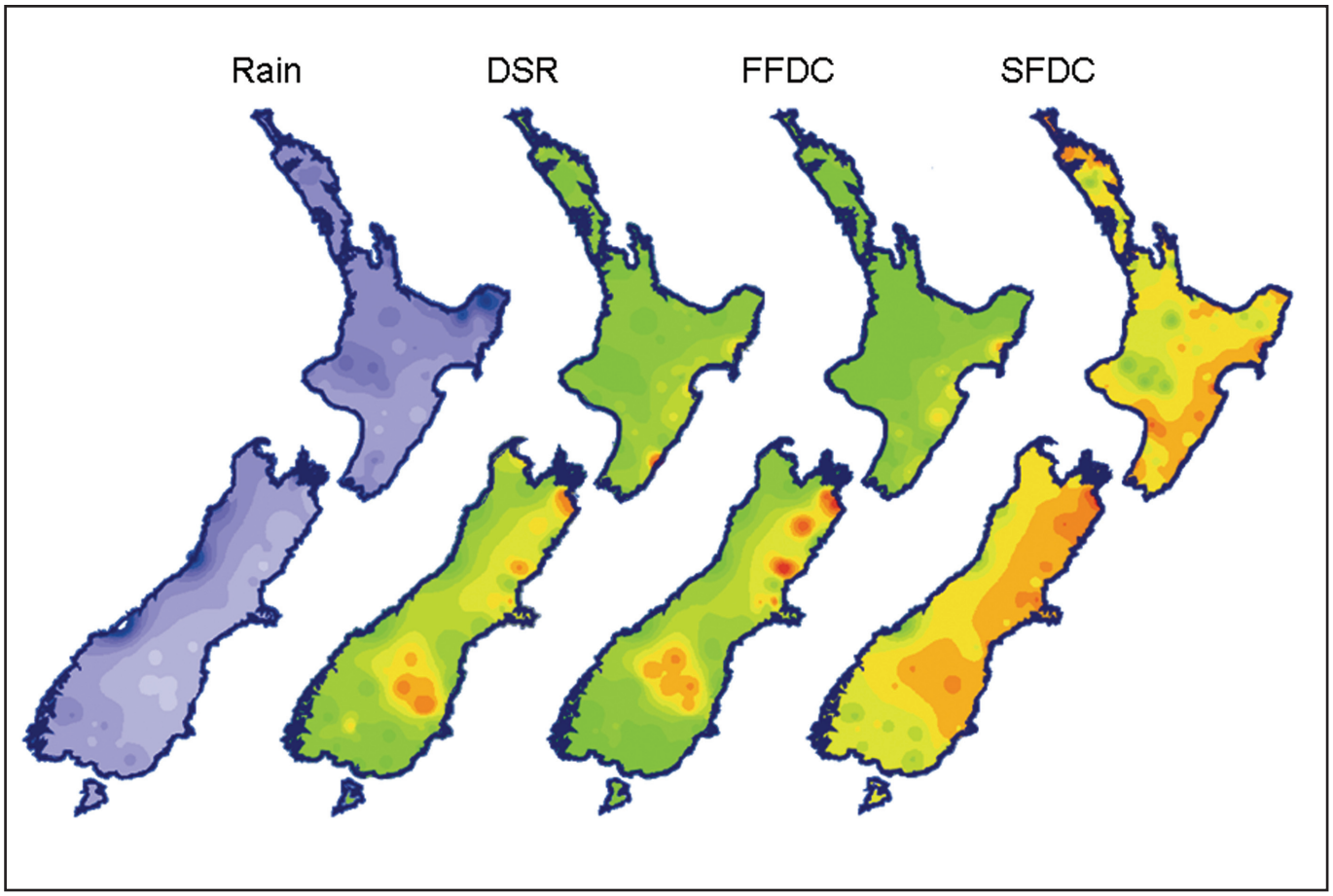

Figure 2. Fire climate severity across New Zealand, as depicted by the long-term average Daily Severity Rating (DSR) and the combined number of days of Very High and Extreme (VH+E) fire danger class for Forest (FFDC), and for Scrubland (SFDC). Severity tends from high (red) to low (green). Mean annual rainfall is also included for comparison, tending from dry (light blue) to wet (dark blue).

daily fire weather data in a climatological database allows analyses of current, past, and even future fire danger.

New Zealand fire climate

New Zealand has a varied climate ranging from warm, subtropical in the north to cool, temperate in the south. Mountain chains extending the length of New Zealand provide a barrier to the prevailing westerly winds, dividing the country into many diverse microclimates from semi-arid (rainfall <350 mm/yr) to sub-tropical (rainfall >7000 mm/yr). As a result, fire risk varies considerably for different parts of the country. In general, the eastern and northern parts of both of the two main islands tend to have the most severe fire climates, as they are most prone to foehn wind and drought conditions. Unlike many other parts of the world where more stable continental climates prevail, problem fire weather can also occur at almost any time of the year due to New Zealand's milder, maritime environment.

New Zealand's fire climate has been the focus of much research in recent years, following development of a fire climate database (based on data from the NRFA's fire weather archive and NIWA's National Climate Database). This has included comparisons of fire season severity (Pearce 1996, Pearce *et al*. 2003), and identification of distinct fire climate regions (Heydenrych *et al*. 2002) and weather patterns contributing to severe fire seasons in different parts of the country (Heydenrych *et al*. 2001, Gosai *et al*. 2003, 2004, Griffiths 2004). The effects of interannual and longer term climate variability (Pearce *et al*. 2007) and future climate change (Pearce *et al*. 2005) on fire danger across the country have also been investigated.

Two measures of fire season severity have been used to describe the influence of climate on fire danger levels - the Daily Severity Rating (DSR) and the fire danger class frequency (days of VH+E). These measures integrate the drying influences of higher temperatures, decreased rainfall and increased wind speeds on potential fire intensity, and indicate the increasing amount of work and difficulty of controlling a fire as fire intensity increases (Van Wagner 1987). The DSR is a numerical rating of the daily fire weather severity at a particular station, based on the Fire Weather Index value, which can be averaged over any period to provide monthly or seasonal severity ratings (Harvey *et al*. 1986). The Cumulative Daily Severity Rating (CDSR) is the total of the daily DSR values summed across

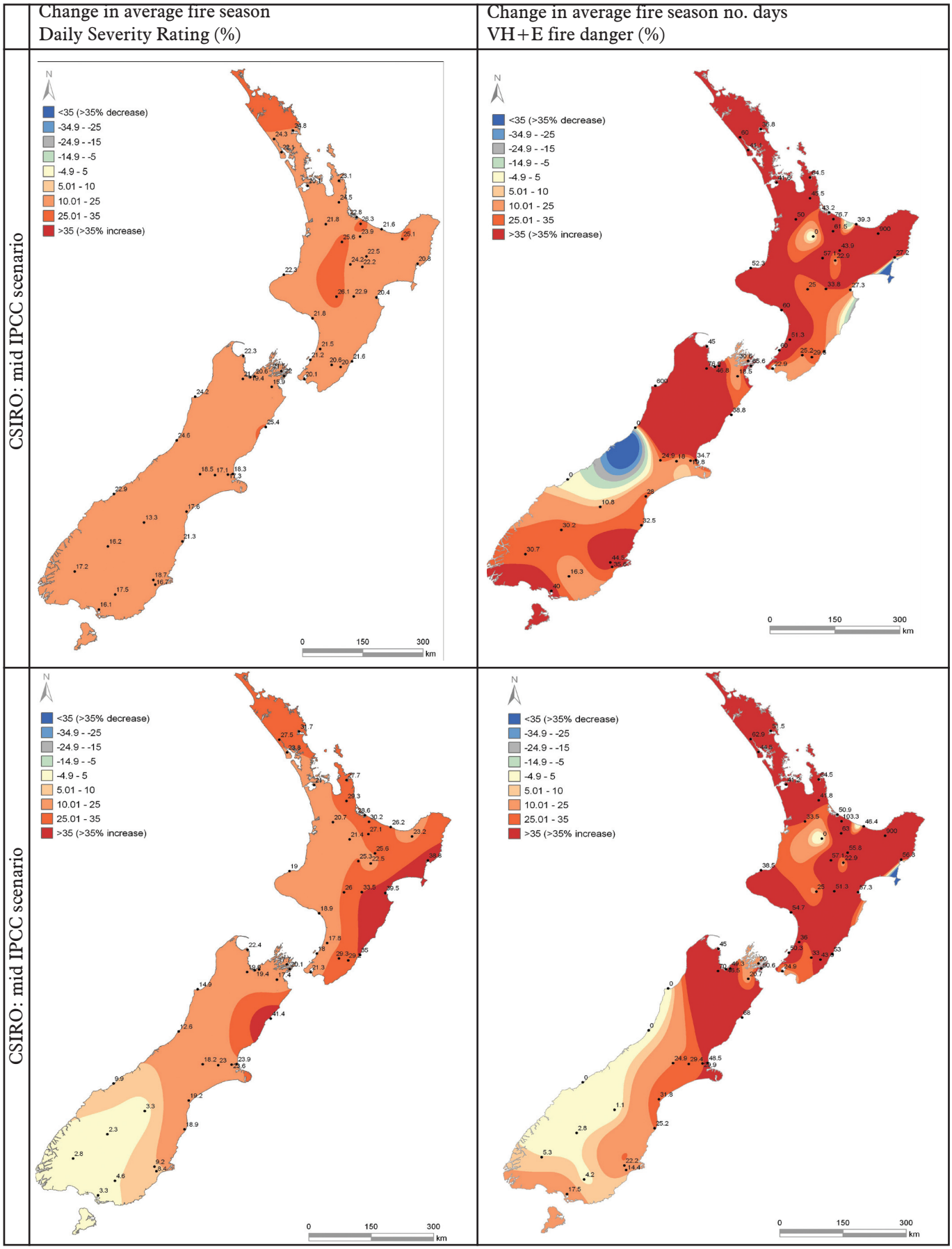

Figure 3. Changes in fire season severity and fire danger class frequency associated with the CSIRO and Hadley mid-IPCC climate change model scenarios averaged over fire season months (October-April) at 52 weather station locations across New Zealand.

an entire year. The fire danger class scheme as developed by Alexander (1994) includes five fire danger classes - Low, Moderate, High, Very High, and Extreme - that provide an indication of the increasing difficulty of fire suppression as fire intensity increases. The fire danger class frequency refers to the number of days occurring in the Very High and Extreme (VH+E) fire danger classes, which represent the conditions under which it will be difficult, if not impossible, to control fires with conventional suppression techniques due to their intensity.

Fire danger climatology database and summaries

In an effort to improve knowledge on the fire climate of New Zealand, the only previous study of New Zealand's fire climate (Pearce 1996) was updated to include more recent climate data, and extended to include a greater number of available weather stations (Pearce *et al*. 2003). The principal output from the analysis was a summary containing the long-term average and extreme values of weather and FWI System components for 127 station locations. Summary statistics for each station were also used to identify the individual weather stations and geographic regions with the most severe fire climates. Fire climate severity was determined using the average of rankings for long-term mean Cumulative Daily Severity Rating (CDSR) and number of days in the Very High and Extreme (VH+E) fire danger classes for Forest (FFDC) and Scrubland (SFDC) for each station and region.

Stations in the Marlborough and Canterbury regions demonstrated the highest values of the three fire climate severity measures (Table 1). At the other end of the scale, the West Coast, Taranaki and Waikato regions had the least severe fire climates. For individual station locations, three stations in Marlborough - Awatere Valley, Woodbourne Aero (i.e., Blenheim) and Molesworth - had the most severe fire climates. Christchurch Aero in Canterbury and Castle Point in Wairarapa were the other two stations in the top five. The seven stations with the least severe fire climates included Opouteke in Northland, Marco in Taranaki, Athol in the Waikato, Waimarino Forest in Wanganui/Manawatu, and all three stations - Westport, Hokitika Aero and Haast - from the South Island's West Coast. These stations are generally characterised by the highest annual rainfalls. [See Table 5 (pages 19-22) in Pearce *et al*. (2003) for the

Table 1. Ranking of regional fire climate severity based on stations included in the fire climatology analysis of Pearce et al. *(2003), using the average of rankings for long-term mean Cumulative Daily Severity Rating (CDSR) and number of days of Very High and Extreme (VH+E) fire danger class for Forest (FFDC) and Scrubland (SFDC).*

Region	No. Stations	Average CDSR	VH+E FFDC (days)	VH+E SFDC (days)	Rank CDSR	Rank FFDC	Rank SFDC	Average Rank
Canterbury	10	900	21.8	234.2	1	1	3	1.7
Marlborough	7	795	21.1	237.7	2	2	2	2.0
Otago	10	762	16.1	223.8	3	3	6	4.0
South Cant'y	4	636	14.6	228.2	5	4	5	4.7
Eastern N.I.	13	579	14.3	231.3	6	5	4	5.0
Wellington	4	435	6.8	248.2	8	7	1	5.3
Wairarapa	7	745	13.3	216.2	4	6	8	6.0
Nelson	4	576	5.2	211.1	7	8	10	8.3
Northland	10	285	4.7	217.8	11	10	7	9.3
Wang/Man	13	306	4.9	205.1	10	9	11	10.0
Central N.I.	13	284	4.6	211.9	12	11	9	10.7
Southland	9	346	3.3	181.8	9	12	15	12.0
Auckland	9	209	2.2	194.8	13	13	13	13.0
Waikato	6	180	1.7	191.2	14	14	14	14.0
Taranaki	5	157	0.9	196.7	15	15	12	14.0
West Coast	3	44	0.0	135.0	16	16	16	16.0

full list of fire climate severity rankings for individual weather stations].

Impact of climate change on future fire danger

A growing body of international evidence suggests that future fire activity is likely to increase as a result of global warming and associated climate change (IPCC 2007). Pearce *et al*. (2005) undertook a study to determine the likely changes in fire danger under different scenarios of climate change for New Zealand. The research applied regional climate change scenarios for the 2080s to the long-term daily weather records for individual stations in the fire danger climatology database.

Two General Circulation Models (GCMs), CSIRO and Hadley, with contrasting spatial patterns of climate change across the country were used to investigate the effects on fire danger. GCM model outputs were "downscaled" to 52 weather station locations using a statistical technique developed for New Zealand by NIWA (Mullan *et al*. 2001). Mean monthly offsets for temperature and rainfall were used to recreate daily fire weather and fire danger records for each station. High, low, and mid-range scenarios of climate change were generated for each model to cover the range of possible future climate outcomes.

Results indicate that New Zealand is likely to experience more severe fire weather and fire danger, especially in the Bay of Plenty, east of both islands and central (Wellington/Nelson) regions (Figure 3). In several cases (e.g. Gisborne, Napier, Christchurch), average seasonal severity ratings increased by more than 25-65%, and the number of days of VH+E forest fire danger increased by more than 20 days (> 50%). More detailed findings on changes for individual locations are contained in Pearce *et al*. (2005). The likely effects of the predicted increases in fire risk include:

- longer fire seasons, increased drought frequency, and associated increases in fuel drying;
- easier ignition, and therefore the possibility of a greater number of fires;
- drier and windier conditions, resulting in faster fire spread, larger areas burned, and increased fire suppression costs and damages;
- greater fuel availability and increased fire intensities, more prolonged mop-up, increased resource requirements and more difficult fire suppression;
- increased frequency of thunderstorms and lightning.

Conclusion

In recent years, considerable research on describing and predicting New Zealand's fire climate has been undertaken. A key element of this has been the development of a fire climatology database of daily fire weather and fire danger information for weather station locations across the

country. This database has provided the basis for a range of studies, including comparisons of the severity of fire climates in different parts of the country, prediction of the severity of fire seasons, and projection of likely effects of climate variability and change on fire danger.

It is planned to continue to update the fire climatology database at regular intervals to enable further research on improving description of New Zealand's fire climate to be undertaken. The database is contributing to an increased awareness of seasonal fire danger trends, improved regional fire danger forecasts, and prediction of fire season severity and climate change effects. By indicating potential fire behaviour and suppression requirements, both in the short-term and into the future, rural fire authorities are able to make more informed fire management decisions, leading to more effective and efficient use of resources and, ultimately, a reduction in the incidence and consequences of wildfires.

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