NIWA
Taihoro Nukurangi

Fire Risk Assessment

A measure to quantify fire risk for New Zealand locations

Prepared for Ministry for the Environment

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Executive summary

The Ministry for the Environment (the Ministry) contracted the National Institute of Water and Atmospheric Research (NIWA) to investigate a measure of fire risk that may be appropriate for inclusion in future Atmosphere and Climate domain reports. The New Zealand Fire Danger Rating was used for this study, specifically the monthly and annual number of days of Very High or Extreme (VH+E) fire danger. New Zealand's National Rural Fire Authority (NRFA) uses the Fire Danger Rating System to monitor fire risk in New Zealand. Fire danger ratings are calculated using four weather variables: 24-hour rainfall, temperature, relative humidity and wind speed. These data are stored in NIWA's National Climate Database, and are subject to comprehensive automatic and manual quality control procedures.

Thirty regionally-representative locations were selected for investigation, and analyses demonstrated considerable variability of VH+E fire danger days. Seven stations out of 30 observe an annual average of more than 10 VH+E fire danger days. The annual average number of VH+E fire danger days range from 41 at Tara Hills (inland South Island), to 0 at Hokitika and Milford Sound. Over the course of a year, the number of VH+E fire danger days are typically highest from January to March, and occur rarely during the winter months.

1 New Zealand Fire Danger Rating

NIWA currently operates the Fire Weather System (FWS) for the National Rural Fire Authority (NRFA), monitoring daily fire danger at multiple sites around the country (http://fireweather.nrfa.org.nz/). The FWS is based on the internationally-recognised Fire Danger Rating System, originally developed in Canada. The system has been modified for New Zealand conditions and has been used by the NRFA for many years.

The Fire Danger Rating System has five categories: Low, Moderate, High, Very High and Extreme (Figure 1). The two highest categories “Very High” or “Extreme” (VH+E) represent a significant risk for large wildfire outbreaks that may require considerable control efforts (e.g. aircraft using chemical fire retardants). Therefore, a count of the number of days where the Fire Danger is VH+E is an excellent indicator of the wildfire risk at that location for a given month or year.

Figure 1: A display board used to communicate daily Fire Danger.

1.1 Calculation of Fire Danger Rating

Daily fire danger rating is calculated at approximately 210 New Zealand climate stations. It is calculated using a combination of four weather variables (wind speed, relative humidity, temperature and 24-hour rainfall), fuel moisture codes (FFMC, DMC and DC), and fire behaviour indices (ISI, BUI, ROS, HFI). Weather data obtained by NIWA from climate stations is typically in hourly or ten minute intervals, however only midday values of each weather variable are required to calculate the fire danger rating. The fire behaviour indices provide quantitative estimates of fire behaviour based on fuel, topography and weather. Fuel and topography information is unique to each climate station, and has been derived by the NRFA from Land Information New Zealand (LINZ) geographic databases. A fuel type may be one of “forest”, “grass” or “scrub”. Subsequently, the calculation of fire danger ratings at each station is based on the associated fuel type selected. Note a glossary of abbreviations is provided in Section 5. A schematic of the Fire Danger Rating components is shown in Figure 2.

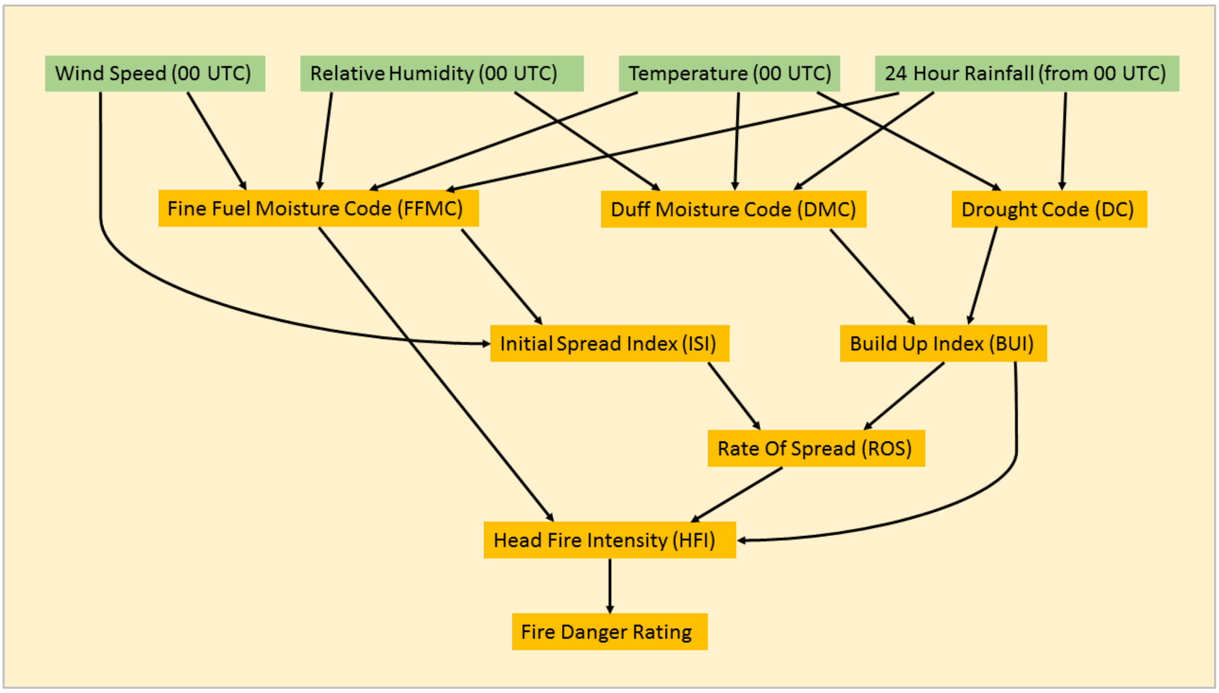

Figure 2: Components required to calculate the Fire Danger Rating.

1.2 Selection of regionally-representative sites

Of the approximately 210 climate stations where fire danger ratings are calculated, 30 were selected for this investigation. The Ministry requested, where possible, that these be the same 30 locations analysed for other climate datasets provided to the Ministry, namely Auckland, Wellington, Christchurch, Whangarei, Hamilton, Tauranga, Taupo, Rotorua, Gisborne, Napier, New Plymouth, Whanganui, Nelson, Timaru, Dunedin, Invercargill, Kerikeri, Whangaparaoa, Taumarunui, Waiouru, Dannevirke, Masterton, Blenheim, Hokitika, Reefton, Lake Tekapo, Tara Hills, Queenstown, Milford Sound and Gore. Table 1 describes the metadata for the stations selected in this study.

Table 1: Station metadata.

Location	Station selected	Latitude, Longitude (decimal degrees)	Fuel type
Auckland	Clevedon Coast Raws	-36.922, 175.008	Grass
Blenheim	Blenheim Aero Aws	-41.523, 173.865	Grass
Christchurch	Bottle Lake Forest Raws	-43.470, 172.682	Forest
Dannevirke	Dannevirke Ews	-40.208, 176.110	Grass
Dunedin	Traquair Raws	-45.811, 170.131	Forest
Gisborne	Gisborne SYNOP	-38.660, 177.984	Grass

Location	Station selected	Latitude, Longitude (decimal degrees)	Fuel type
Gore	Gore Aws	-46.115, 168.887	Grass
Hamilton	Hamilton Aws	-37.865, 175.336	Grass
Hokitika	Hokitika SYNOP	-42.712, 170.984	Forest
Invercargill	Slopedown Raws	-46.392, 169.132	Forest
Kerikeri	Waitangi Forest Raws	-35.283, 173.986	Forest
Lake Tekapo	Tekapo Raws	-44.001, 170.404	Grass
Masterton	Holdsworth Station Raws	-40.912, 175.559	Forest
Milford Sound	Secretary Island SYNOP	-45.221, 166.886	Forest
Napier	Napier Aero SYNOP	-39.461, 176.859	Grass
Nelson	Hira Raws	-41.282, 173.33667	Forest
New Plymouth	New Plymouth SYNOP	-39.008, 174.178	Grass
Queenstown	Queenstown Aero SYNOP	-45.024, 168.737	Grass
Reefton	Reefton Ews	-42.116, 171.860	Forest
Rotorua	Rotorua Aero Aws	-38.107, 176.316	Grass
Tara Hills	Tara Hills Aws	-44.528, 169.890	Grass
Taumarunui	Waimarino Forest Raws	-39.399, 175.189	Forest
Taupo	Taupo SYNOP	-38.744, 176.081	Forest
Tauranga	Tauranga Aero SYNOP	-37.673, 176.196	Grass
Timaru	Timaru Aero SYNOP	-44.305, 171.225	Grass
Waiouru	Tapuae Raws	-39.995, 175.723	Grass
Wellington	Wellington Aero SYNOP	-41.335, 174.805	Grass
Whanganui	Wanganui,Spriggens Park Ews	-39.939, 175.045	Grass
Whangaparaoa	Mahurangi Forest Raws	-36.364, 174.572	Forest
Whangarei	Whangarei Aero Aws	-35.769, 174.364	Grass

2 Data quality control

All climate data used in the calculation of Fire Danger Ratings are stored in NIWA's National Climate Database (CLIDB). While no guarantee is made regarding the accuracy of the data in CLIDB, all reasonable skill and care has been applied so that the data are as reliable as possible.

The following quality control procedure is undertaken for all data in CLIDB. As observed values are transferred into permanent data tables in the database (e.g. MAX_MIN_TEMP, RAIN etc.) from temporary input tables (e.g. RMS_AWS, RMS_DLYCLI etc.) they are automatically inspected for errors. These are either gross errors when values fall outside very wide universal limits so that an error flag is given the value "E" and the observation is not transferred into CLIDB, or they are potential errors as they lie sufficiently outside of the 1 or 99 percentile for that place/time so that an error flag is given the value "W" and the observation is transferred into CLIDB.

Most data originating from the various data streams entering CLIDB (i.e. of different origins or message types) do so as frequently as possible (e.g. RMS_AWS is hourly but the suite of UPPER_AIR messages are every 6 hours). These frequent transfers do not report errors and warnings but daily collectives are also run and the errors and warnings are reported with these runs. The daily collective runs also log any errors or warnings into the ERRLOG and WARNLOG tables except for AWS data which do not have a daily collective but a daily reporting/logging process runs just after midnight. Time series plots centred on the observation with a "W" warning are generated and the 1 and 99 percentiles are also used to standardise observations and facilitate manual checking of the data.

After manual inspection and depending upon the inspection outcome, the data are either unchanged or corrected (with associated quality flags) or deleted from CLIDB. Data remaining in the database are deemed sufficiently high quality for inclusion in the station data record, and for subsequent data analysis. Should users of the climate data query its validity, then additional user-initiated manual data checks are also made.

2.1 Fire Weather System data

Specific observations required to calculate the Fire Danger Rating are stored in a permanent Fire Weather System data table (FWSYS_DATA). These data are either loaded directly into FWSYS_DATA, or copied from the relevant permanent table. Quality control flags are included for every datum in the Fire Weather System data table (Table 2). Only midday values of the relevant weather variables are required to calculate the Fire Danger Rating. Missing weather variable data are substituted with interpolated data using *ANUSplin*: a software tool that takes data values from irregularly-spaced observing sites and provides interpolated values at regularly spaced grid point locations. Specifically, the data are calculated by the ANUSplin trivariate (three independent variables: easting, northing and a third variable, e.g. elevation) thin-plate smoothing spline interpolation methodology, described by Wratt et al. (2006).

Table 2: Fire Weather System quality control flags.

Code	Reliability	Comment
NULL	As read	Default for all incoming data that are assumed to be correct
1	Corrected	Raw data re-entered in correct format, table, etc.
2	Warning accepted	Warning from spatial or range checks that has been checked and accepted by human intervention
3	Warning spatial check	Warning arising from spatial check
4	Warning range check	Warning arising from range check
5	Computed estimate	Value interpolated or derived from other data using a documented procedure or model
6	Manual estimate	Value derived from mental arithmetic
7	Suspect estimate	A "neutral" value entered as an infill value to complete a time series
8	Error	Known errors (flagged as awaiting correction or deletion)

Note, 11 of the 30 stations selected in this study are "Raws" stations, i.e. stations owned and operated by the New Zealand Fire Service (NZFS). In 2011, NIWA carried out a bulk transfer of the data from the NZFS database to CLIDB. Subsequent to the bulk transfer, "Raws" data is ingested directly into CLIDB. NIWA has no record as to the quality control processes performed on the "Raws" data prior to the bulk transfer in 2011. However, these "Raws" data were reprocessed using the data quality control methods described above, and there is no evidence to suggest that climate data at these stations prior to 2011 is any less accurate than post-2011.

Monthly data quality reports of Fire Weather System data are generated automatically for each station. These include the number of days of data available for the month, and specify the percentage of interpolated data for each weather variable. NIWA are confident that the quality of the data is sufficient for analyses and research purposes due to data quality control procedures in place.

3 Fire danger analyses

Monthly and annual counts of days where the fire danger rating was VH+E were calculated from all available data for each of the 30 stations. These data were collated in Excel files and sent to the Ministry. Figures 3 and 4 show the average annual count of VH+E days for North Island and South Island locations, respectively. Napier observes an annual average of 28 days of VH+E fire danger, which is the highest average for North Island locations included in this study. Tara Hills observes an annual average of 41 days of VH+E fire danger, which is the highest average of the South Island locations included in this study. Wellington observes a relatively high annual average of 15 days of VH+E fire danger, which is likely a result of the strong winds observed in the city. Seven stations out of 30 observe an annual average of more than 10 VH+E fire danger days.

Figures 5 and 6 demonstrate the annual and monthly variability of VH+E fire danger days in Blenheim, respectively. Blenheim's highest annual total VH+E fire danger days is 74 in 2001, and its lowest annual total is 5 days in 2013. Notably, the Marlborough region received greater than 150% of normal January rainfall in 2013, which may have contributed to the low annual number of days observed. This is because the highest monthly number of days of VH+E fire danger are typically observed in January (Figure 6). In Blenheim, monthly VH+E fire danger days peak from January – March, and VH+E fire danger days are exceptionally uncommon during the winter months.

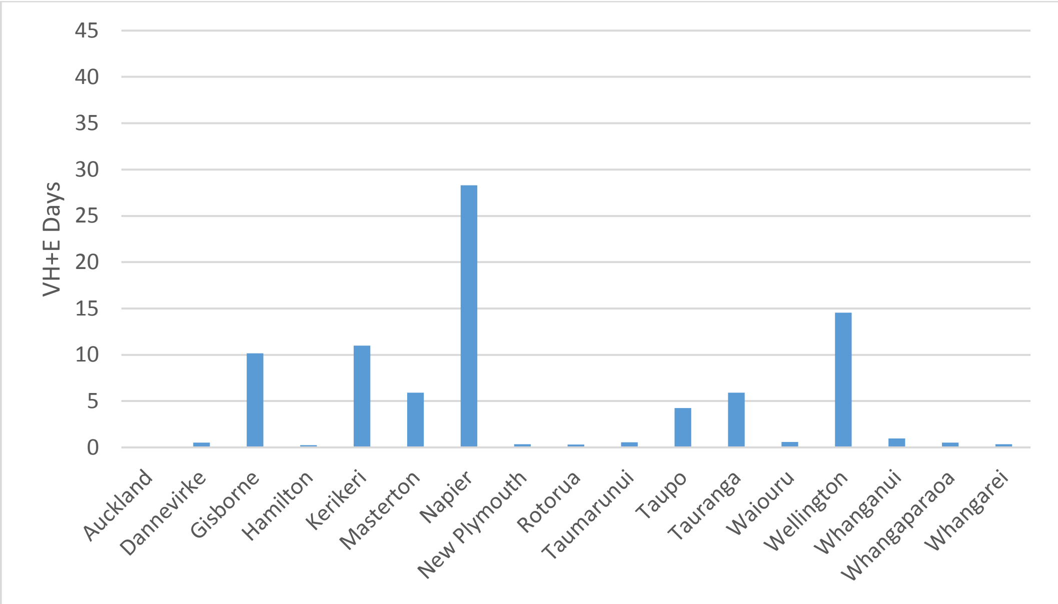

Figure 3: **Average annual number of days with Very High or Extreme fire danger, North Island locations.**

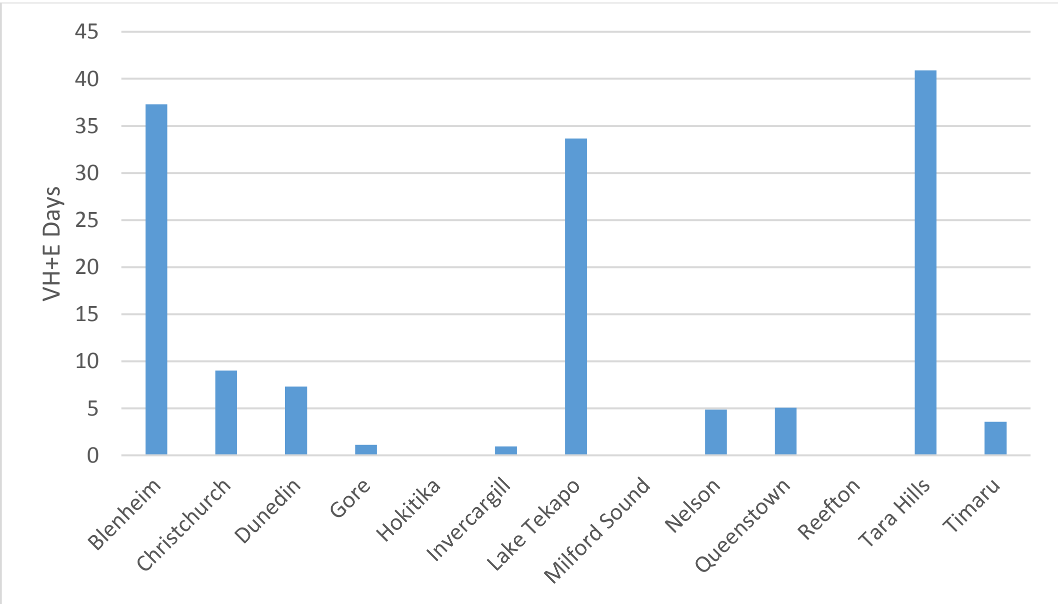

Figure 4: **Average annual number of days with Very High or Extreme fire danger, South Island.**

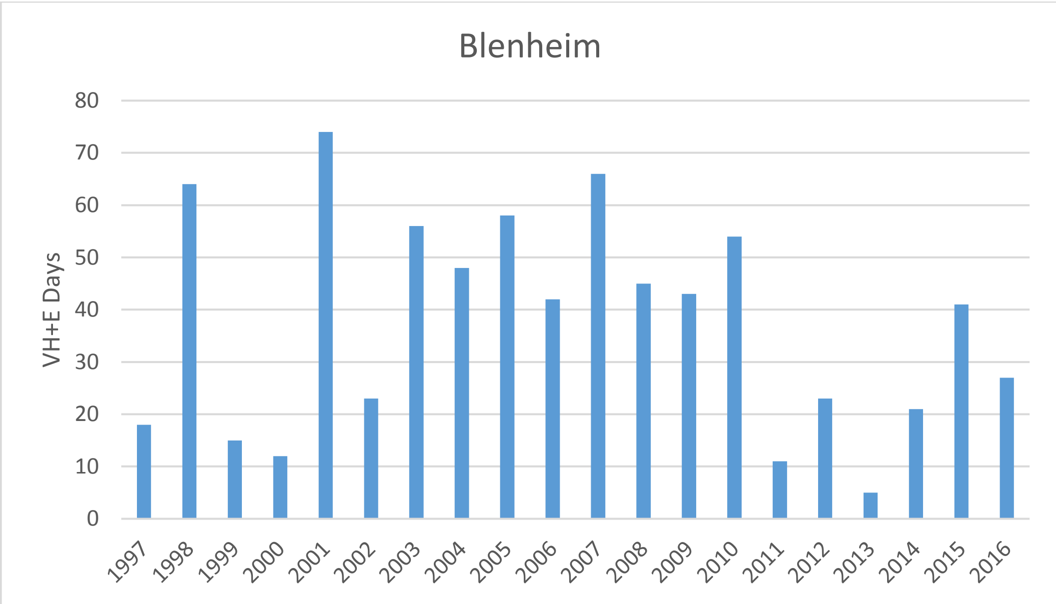

Figure 5: Annual number of VH+E fire danger days, Blenheim.

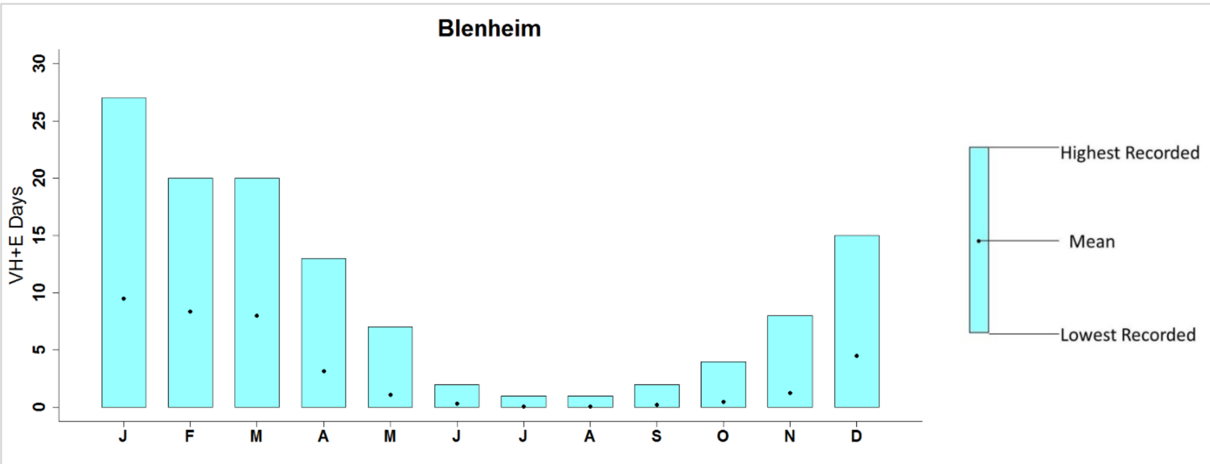

Figure 6: Monthly variability of VH+E fire danger days, Blenheim.

3.1 Example data quality report

The most recent monthly Fire Weather System data quality report (May 2017) was examined to provide insight on the availability and infilling of data for each of the 30 stations selected for this study. NIWA anticipates that these are a fair representation of the typical monthly data quality. These reports are separated into each weather variable below:

24-Hour Rainfall:

- 31 days of data available at all 30 stations.
- Data infill required for 17 out of 30 stations.
- Percentage of data infilled ranged from 0 – 100%, with an average of 5.1% and a median of 3.2%.

- 100% data infill required at *Secretary Island SYNOP*. The issue at this station appears to be with the transfer of data to FWSYS_DATA and is under further investigation.

Temperature:

- 31 days of data available at all 30 stations.
- Data infill required for 9 stations.
- Percentage of data infilled ranged from 0 – 100%, with an average of 4.3% and a median of 0%.
- 100% data infill required at *Secretary Island SYNOP*.

Relative Humidity:

- 31 days of data available at all 30 stations.
- Data infill required for 9 stations.
- Percentage of data infilled ranged from 0 – 71%, with an average of 3.3% and a median of 0%.
- 71% data infill required at *Secretary Island SYNOP*.

Wind Speed:

- 31 days of data available at all 30 stations.
- Data infill required for 10 stations.
- Percentage of data infilled ranged from 0 – 100%, with an average of 7.4% and a median of 0%.
- 100% data infill required at *Hira Raws*, which appears to be suffering an issue with its anemometer and is under further investigation.

3.2 Recommendation

The Fire Danger Rating System is a relevant measure of fire risk in New Zealand, and continues to be used by the NRFA. This report examined the monthly and annual count of VH+E fire danger days for 30 New Zealand locations. NIWA is confident that this is a worthwhile index for the Ministry to use in future Atmosphere and Climate domain reports.

In future, the Ministry may wish to include additional locations to subsequent analyses to enable an improved understanding of the regional variability of VH+E fire danger days. Increasing the scope of the investigation to examine all fuel types at each location may be a useful addition to analyses of regional variability. The potential to produce maps from the data analyses could also be explored.

4 Acknowledgements

The authors wish to acknowledge Stuart Waring from the New Zealand Fire Service (NZFS) for permission to use NZFS data in this investigation, and Bernard Miville (NIWA) for assistance with this project.

5 Glossary of abbreviations and terms

Aws	Automatic Weather Station. Owned and operated by MetService.
BUI	Build Up Index. Combines the DMC and DC and represents the total amount of fuel available for combustion.
CLIDB	National Climate Database. Operated by NIWA.
DC	Drought Code. A rating of the average moisture content of deep, compact, organic layers. This code is a useful indicator of seasonal drought effects of forest fuels and amount of smouldering in deep duff layers and large logs.
DMC	Duff Moisture Code. A rating of the average moisture content of loosely compacted organic layers of moderate depth.
Ews	Electronic Weather Station. Owned and operated by NIWA.
FFMC	Fine Fuel Moisture Code. An indicator of the relevant ease of ignition and flammability of fine fuels.
FWS	Fire Weather System. Operated by NIWA, and monitors daily fire risk throughout New Zealand.
HFI	Head Fire Intensity. Estimates the intensity of the head of a fire (kW/m).
ISI	Initial Spread Index. Combines the effect of wind speed and the FFMC, providing a numerical rating of fire spread rate.
LINZ	Land Information New Zealand.
NIWA	National Institute of Water and Atmospheric Research Ltd.
NRFA	National Rural Fire Authority
NZFS	New Zealand Fire Service
Raws	Rural Automatic Weather Station. Owned and operated by NZFS.
ROS	Rate of Spread. Combines the ISI and BUI to indicate the intensity of a spreading fire. Dependent on fuel type.
SYNOP	Automatic weather station owned and operated by MetService.
VH+E	"Very High" or "Extreme" fire danger rating

6 References

Wratt, D.; A. Tait; G. Griffiths; P. Espie; M. Jessen; J. Keys; M. Ladd; D. Lew; W. Lowther; I. Lynn; N. Mitchell; J. Morton; J. Reid; S. Reid; A. Richardson; J. Sansom and U. Shankar (2006). Climate for crops: Integrating climate data with information about soils and crop requirements to reduce risks in agricultural decision-making. Meteorological Applications, 13, pp 305–315.