

Fire Technology Transfer Note

Number - 30

November 2005

Improved Fuel Type and Fuel Load Maps: a GIS System for Mapping Fire Behaviour Potential

By Tonja Opperman, Wildfire Scientist and Caroline Coquerel, GIS Specialist

Introduction

Quantifying and spatially displaying potential fire behaviour such as rate of spread (ROS) and fire intensity is critical for informed fire management decision-making. However, determining potential fire behaviour first requires assigning fuel models to local vegetation types to calculate available fuel load (AFL). Linking these calculations to a landcover database allows us to represent AFL variations across the landscape; such a link is provided by the new LCDB2 Land Cover Database for New Zealand released in 2004 (Thompson *et al.* 2004).

This document describes our methodology for creating improved maps of fuel types and AFL, which can be used to update potential fire maps using a Geographic Information System (GIS). We explain terminology, how mathematical models were assigned to New Zealand vegetation types, and the resulting maps. We further discuss management applications and future work to develop fire behaviour maps by integrating more refined weather data. Any fire manager interested in using the updated New Zealand Wildfire Threat Analysis (WTA) hazard layers (NRFA 2005, Briggs *et al.* 2005), or using fuel type maps for planning will benefit from understanding the underlying principles described here.

Definitions

Some terms used in this paper require definitions to avoid confusion. Land cover classes are the categories identified from the satellite image, such as "grey scrub" or "river". We use the term vegetation type or cover type to describe the land cover classes that support combustible vegetation; these descriptions are often specific in regards to plant associations or species. A fuel type is an association of fuel elements that will exhibit similar fire behaviour under specified weather conditions (Merrill and Alexander 1987) and are commonly referred to as "grass" or "scrub" fuel types. Vegetation types are usually grouped into fuel types depending on which part of the fuel profile carries the fire's leading edge and contributes to the expected fire behaviour. Vegetation types can contain more than one designated fuel type depending on structure or season. For example, a radiata pine vegetation type could be best represented by a grass fuel type if the understory is dominated by grass, or a slash fuel type if there is continuous dead and down woody material. Following Canadian conventions, fuel types are often designated by shorthand descriptors such as "C-6" for pine plantations or "O-1b" for grasslands (FCFDG 1992). To predict fire behaviour, each fuel type must have either constant values or associated fuel load models to describe the availability of fuels, and fire behaviour models that describe ROS and fireline





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intensity¹ under specific environmental conditions. These models are in the form of mathematical equations. AFL is a critical factor in calculating fireline intensity and can be a constant value or, in the case of forest fuel types, can be determined by a mathematical relationship between fuel type and the Buildup Index (BUI) of the Fire Weather Index (FWI) system (NRFA 1993). Several customised fuel types can result from just a few equations, because each equation can have multiple parameters, and each parameter can be assigned a unique coefficient to represent a fuel type. Understanding the difference between these terms is necessary in order to follow our methodology.

Background

The work described in this document builds upon and refines previous attempts to map fuels and potential fire behaviour. Borger and Pearce (2000) incorporated several data sources to assign available fuel load (AFL) and rate of spread (ROS) models to New Zealand vegetation types in Landcover Database Version 1 (LCDB1) from 1997, which had only nine combustible vegetation types. They used constant AFL values for grass, shrub, and wetland fuel types based on Fogarty and Pearce (2000). AFL and ROS models were either directly adopted from the Canadian Forest Fire Behaviour Prediction System (FCFDG 1992), or modified based on expert opinion.

Leathwick and Briggs (2001) also used LCDB1, plus information from Borger and Pearce (2000) to develop layers for the New Zealand WTA (NRFA 2005). They used the Borger and Pearce (2000) constant values for AFL, but calculated BUI from the average of the highest 20% of fire season days. This resulted in AFL maps that varied as a function of fire climate. Leathwick and Briggs (2001) created nationwide maps of Fire Weather Index (FWI), AFL, ROS, and fire intensity that were further developed into web-based informational tools (Pearce and Majorhazi 2003). Briggs et al. (2005) used the refined equations and coefficients described in this Fire Technology Transfer Note to produce a significant upgrade to the New Zealand WTA.

Methods

Generalised equations with consistent parameters

We considered three different equations for available fuel load (AFL), and five for rate of spread (ROS). Coquerel (2005) found that current documentation showed parameters were not used consistently from one equation to another in terms of their meaning or values. For example, a

parameter of the same name might be used in one equation to represent a multiplier and in another to represent a power, making the use of multiple equations in a spreadsheet or Also, the same GIS very confusing. parameter sometimes had inconsistent coefficients, with values from -0.1 to 50 (Table 1). Coquerel (2005) analysed these multiple equations to create one generalised equation for AFL and one for ROS (Appendix A), each with consistent parameters (Table 2). Although coefficients are still different to reflect expected variation in fire behaviour, there are no longer coefficients ranging from -0.02 to 50 for the same parameter. The generalised equations used for the analysis described in this paper are consistent with their original Canadian sources (FCFDG 1992).

Table 1. Inconsistent coefficients were assigned to the same parameters for different ROS equations representing various vegetation types. Different ROS equations are indicated in the first column, parameters along the top row, and coefficients in the table.

ROS	P1	P2	Р3	P4	Р5	DoC%
ROS	1					
ROS	20					
ROS1	2460	-0.1	1.5			
ROS1	4428	-0.1	1.5			
ROS1	4920	-0.1	1.5			
ROS2	11400	-0.031	1.4	0.02		60
ROS2	15000	-0.035	1.7	0.02		100
ROS3	1800	-0.0232	1.6	0.9	32	
ROS3	1800	-0.08	3.0	0.8	62	
ROS3	4500	-0.0297	1.3	0.75	38	
ROS4	50	50				
ROS4	60	40				

¹ Fireline intensity, or head fire intensity (HFI), is a function of available fuel load and rate of spread (Byram 1959).

Assigning fuel types, equations, and coefficients to vegetation types

Vegetation types from LCDB2 were grouped into fuel types based on expected fire behaviour. This grouping aided in assigning appropriate coefficients for each AFL and ROS equation. Choices were based on similar overseas models (e.g. Canada's C-6) and expert opinion. Opperman (2005) documented the basis for all coefficients. Tables B1, B2, and B3 (Appendix B) serve as the basis for maps because they demonstrate the links between LCDB2 land cover classes, assigned fuel types, equations, parameters and coefficients used to predict AFL and ROS.

Grouping vegetation types to facilitate fuel type mapping

LCDB2 vegetation types were grouped into a reasonable number of fuel types to improve the appearance and utility of the maps. These maps are more useful when users can recognise a fuel type in the map legend and recognise the relative fire behaviour potential it represents, a difficult

process with very small polygons representing 32 vegetation types. Vegetation types were grouped in two ways to display fuel types for different fire management needs. Finally, all the data for LCDB2, fuel and models were types loaded into a database to process in a GIS. Data were processed, values were geographically calculated and AFL maps were produced for a constant BUI value of 60, which was represent chosen to nationwide average "dry" conditions.

Table 2. Consistent coefficients now assigned to parameters after the ROS equations were homogenised into a single equation with consistent parameters. The original ROS equation type is retained by the designator in the first column.

ROS	рр	p1 ₁	p1₂	p2 ₁	p2 ₂	p3₁	p32	p4	р5	DoC%
ROS		1								
ROS		20								
ROS1		2460		-0.1		1.5				
ROS1		4428		-0.1		1.5				
ROS1		4920		-0.1		1.5				
ROS2		11400		-0.031		1.4				60
ROS2		15000		-0.035		1.7				100
ROS3		1800		-0.0232		1.6		0.9	32	
ROS3		1800		-0.08		3.0		0.8	62	
ROS3		4500		-0.0297		1.3		0.75	38	
ROS4	50	1800	1800	-0.0697	-0.0232	4.0	1.6	0.8	50	
ROS4	60	1800	1800	-0.0697	-0.0232	4.0	1.6	0.8	50	

Results & Discussion

Documented Crosswalks from Vegetation Type to Fuel Type

By clearly documenting the connection between vegetation types and fuel types, the tables in Appendix B suggest a crosswalk fire managers can use to choose fire behaviour fuel models based on vegetation types. Although the resulting map may not be accurate at small scales, the tabular information can be used in concert with the *Field Guide to Fire Behaviour in New Zealand Fuel Types* (Pearce and Anderson 2004) to understand which fuel models are appropriate for a particular vegetation type.

Fuel Type Classifications for Different Fire Management Needs

We devised both "simplified" and "detailed" fuel type classifications, each meant to serve different fire management purposes (Table 3). The Simplified classification has three fuel types labelled either grassland, scrub or forest, representing those fuel types with identified fire danger criteria (Alexander 1994). This display is best used for maps of fuel types used in the New Zealand Fire Danger Rating System (Figure 1). The Detailed classification has nine fuel types, differentiating the basic grassland, scrub and forest types into more descriptive categories. This is a more dissected representation of fuel types on the landscape. Standard fuel type classifications can provide some element of nationwide consistency while still allowing flexibility in map appearance based on local needs.



Figure 1. Having maps of grass, scrub, and forest fire danger vegetation types can help managers use the best index for public fire danger signs.

The two classifications can be applied directly or futher modified for additional purposes. For example, irrigated cropland and non-irrigated pasture grasslands may be important to distinguish in the summer months, but not in spring or winter when degree of grass curing is less of a fire behaviour factor. However, the underlying fuel models used to calculate available fuel load, rate of spread, and fire intensity are fixed and do not change with a change in fuel type classification. Changing the classification only changes how land cover classes are displayed as fuel types on the map.

Several improved maps have been created for immediate use in fire management. Maps displaying the two fuel type classifications are available for the whole of New Zealand (e.g., Figure 2); and the South Island, North Island, and the Canterbury Region (e.g., Figures 3 and 4) from our website².

The Canterbury Region is provided as an example of application at a regional scale. For large fire incidents, the fuel type maps provided here may be the best available products for predicting fire behaviour across large areas.

Improvements in Available Fuel Load Mapping

We have also improved our capability to map dynamic AFL. Previous AFL maps display a single fixed value for all grasslands and for shrublands. We have assigned either dynamic AFL equations and coefficients to each LCDB2 vegetation type, or fixed values. For example, instead of one value to represent fuel load in all scrublands, there are now different values assigned to each category of gorse/broom, grey scrub, flaxland, matagouri, and manuka/kanuka. Although AFL maps are not available from Ensis at this time, Figure 5 is an example of an AFL map created with our new equations and coefficients, and a BUI of 60. Table 3. Two examples of fuel type classifications that display LCDB2 vegetation types for different fire management needs, and how they are related.

Simplified	Detailed				
	Pasture Grassland				
Grassland	Tussock				
	Cropland				
	Wetland				
Scrub	Scrub				
	Mangrove				
	Indigenous Forest				
Forest	Planted Forest				
	Deciduous Hardwood				

² http://www.ensisjv.com/bushfire+research.aspx

Figure 2. Detailed fuel type classification for New Zealand, based on LCDB2 land cover classes. A simplified classification is also available.



Figure 3. Detailed fuel type classification for the Canterbury Region, based on LCDB2 land cover classes. Similar maps are available for the North and South Islands.



Figure 4. Simplified fuel type classification for the Canterbury Region, based on LCDB2 land cover classes. Similar maps are available for the North and South Islands.



Figure 5. Example of an available fuel load (AFL) map for the Canterbury Region, using the generalised AFL equation with newly assigned coefficients for LCDB2 land cover classes.



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Potential Management Applications and Future Developments

All of this work has been loaded in a GIS to easily update and process new maps under various scenarios. There is potential to change some models or coefficients to create customised or more refined available fuel load (AFL) maps with sufficient local fuel type knowledge. For example, if local tussock is either tall and dense or short and sparse, this attribute can be changed in the equations for improved outputs. AFL calculations can be made more locally relevant by changing the constant fuel load values (columns $P1_1$ or $P1_2$ in Table B1). Now that the process is somewhat automated in the GIS, AFL could be run for any BUI value and easily remapped to show dynamic AFLs over time and across a landscape. Additionally, ROS calculations for grass fuel types can be manipulated by changing degree of curing (DoC% column in Table B2) in the database to represent seasonal changes.

The ability to map various fire behaviour scenarios has several management applications, the key of which is improved potential fire behaviour calculations for the Wildfire Threat Analysis (WTA) (NRFA 2005). WTA is a systematic method of spatially identifying the interaction of threats in the form of ignition potential, potential fire behaviour, and economic or social values (Figure 6). This procedure enables informed decisions regarding fire prevention, fire control, and community planning. Understanding which WTA hazard layer contributes most to high risk designations can prompt fire managers to target and prioritise mitigation measures and treatment zones. To date, the WTA procedure has used fixed values for calculating available fuel loads (AFL) and a single fire weather scenario to generate a potential fire behaviour map. This method does not consider, for example, that a BUI of 60 might represent "moderate" fire danger in Canterbury, but "high" fire danger on the West Coast. In future WTA applications, the products described here will improve AFL mapping by using newer satellite imagery, using refined fuel load coefficients in equations, and use spatially variable BUI inputs instead of a fixed value.

Fire managers can use these maps to understand fuel models and potential fire behaviour in their local environments. Various fire weather scenarios based on local historic data can be used to map ROS and fire intensity, noting relative differences among geographic areas. This information can

help managers decide where to set thresholds for resource staffing levels, permits, or closures and restrictions. Potential fire behaviour maps can help managers identify broad areas that require a sitespecific assessment to mitigate fire problems.

The GIS database we created contains all the necessary equations and parameters to calculate and map ROS and fire intensity. However, these fire behaviour outputs require weather inputs and although any weather value could be input to achieve nationwide fire behaviour maps, a project is underway to map New Zealand's fire climate.



Figure 6. Wildfire Threat Analysis flowchart indicating how land cover data, fuel types, fuel loads, and potential fire behaviour (rate of spread, head fire intensity) fit into the overall structure (NRFA 2005).

When complete, the fire climate maps will provide local, spatially distinct weather inputs to calculate fire behaviour for a region. These data will allow calculation of a BUI map that varies with climate. This BUI input, when combined with the AFL map and fire behaviour equations, will replace the current static value of 60 and result in maps that are more sensitive to nationwide fire weather variations.

Limitations

It is important to understand the underlying assumptions made during this process before interpreting map outputs. Although the spatial data provided by LCDB2 are quite useful for fire behaviour modelling because we can map vegetation nationwide, there are limitations. LCDB2 does not contain any other corresponding environmental variables besides the dominant canopy vegetation that was assigned from a satellite image. The LCDB2 layer ignores any vegetation type smaller than 1 hectare and it is suggested that it should be used at a scale of 1:25 000 or smaller (i.e 1:50 000). Using the map at finer scales to prescribe treatments or determine local fire suppression strategies is an inappropriate use of these data. Also, if the vegetation layer is not updated as the landscape changes, the fire-related calculations will reflect reality less over time.

We assigned fuel models from the LCDB2 vegetation types. The disadvantage is that fuel models were assigned based on canopy cover type alone and there may be errors. For example, in areas where grass is a major surface fuel component, LCDB2 may have labelled it as scrub because an aerial view shows more scrub vegetation than grass. Since we are working from the LCDB2 classification, not the original satellite image, we would assign a scrub fuel model when, perhaps, a grass model might better represent potential fire behaviour. We have not performed an analysis to determine the accuracy of fuel model choices; however, we are using the best technology available at this scale, which allows mapping of the entire country. Using canopy vegetation type that was derived from a satellite image as the only source of data to assign fuel models is a limitation of the final map products. Fire managers can ground-truth and fine-tune these layers to meet local needs.

There are still only a few fuel models validated for New Zealand fuel types. In many cases, a "best guess" based on knowledge and experience was used to assign models. With increased distinction between vegetation types and refined fire behaviour models, it may be possible to develop more detailed fuel type classes in the future; for example, separating gorse from broom. Although the methods exist to map dynamic fuel loads, results depend on the accuracy of the vegetation type and the assigned mathematical models. Keeping these data limitations and assumptions in mind when interpreting maps ensures data are properly applied.

Conclusion

This project provides a methodology for creating improved AFL, ROS, and fire intensity maps by using the latest vegetation coverage and rendering equations with consistent parameters and coefficients. It demonstrates refined AFL and fire behaviour fuel models for New Zealand vegetation types using new satellite imagery. Although the process has limitations for application to small areas, the most reasonable equations and coefficients were assigned to nationwide vegetation types. The result is a GIS system that allows efficient updating, system additions, or crosswalking to other data in the future. This process is documented to provide a foundation for on-going work as we improve our understanding of New Zealand fire behaviour. In fact, the AFL information has already been put to use in the refined hazard layer of the NZ WTA. There are also standardised "simplified" and "detailed" fuel type maps available to managers for displaying variation in their local landscapes. We appreciate your feedback on this process and its utility for fire management.

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Appendix A. Generalised equations used for mapping (after Coquerel 2005).

Generalised equations of Available Fuel Load (AFL) in tons/ha, Rate of Spread (ROS) in metres/hour, and Head Fire Intensity (HFI) in kW/m, where BUI is the Build-Up index, ISI is the Initial Spread Index, SCF is the Slope Correction Factor with slope in degrees. Parameters include p1₁, p1₂, p2₁, p2₂, p3₁, p3₂, pp%, which are assigned coefficients for each fuel type.

(1) Available Fuel Load :

$$AFL_{g} = p1_{1}[1 - EXP(p2_{1} * BUI)]^{p3_{1}} + p1_{2}[1 - EXP(p2_{2} * BUI)]^{p3_{2}}$$
(2) Rate Of Spread :

$$ROS_{g} = \left[\frac{pp\%}{100} * p1_{1}(1 - EXP(p2_{1} * ISI))^{p3_{1}} + 0.2 * (1 - \frac{pp\%}{100}) * p1_{2}(1 - EXP(p2_{2} * ISI))^{p3_{2}}\right] \\
* EXP\left(50 * LN(p4) * \left(\frac{1}{BUI} - \frac{1}{p5}\right)\right) * [0.02 * DoC\% - 1]$$
(3) Head Fire Intensity :

$$HFI = \frac{ROS * SCF * FL}{2} \text{ with } SCF = EXP \left(TAN \left(\frac{Slope}{57.29578} \right)^{1.2} * 3.533 \right)^{1.2}$$

Appendix B.

Tables B1, B2, and B3 display links between LCDB2 land cover classes, assigned AFL models/coefficients, and assigned ROS models/coefficients.

Table B1. Available fuel load model and coefficients assigned to LCDB2 vegetation classes. "Class" and "Name" represent original numeric and descriptive values of the land cover types in the LCDB2 database. Different available fuel load equations are indicated by the designator in column "FL". Coefficients are shown for each of the six parameters.

CLASS	NAME	FL	P11	P12	P21	P22	P31	P32
1	Built-up Area		0	0	0	0	0	0
2	Urban Parkland/ Open Space	FL	2	0	1	1	0	0
3	Surface Mine		0	0	0	0	0	0
4	Dump	FL	10	0	1	1	0	0
5	Transport Infrastructure		0	0	0	0	0	0
10	Coastal Sand and Gravel		0	0	0	0	0	0
11	River and Lakeshore Gravel and Rock		0	0	0	0	0	0
12	Landslide		0	0	0	0	0	0
13	Alpine Gravel and Rock		0	0	0	0	0	0
14	Permanent Snow and Ice		0	0	0	0	0	0
15	Alpine Grass-/Herbfield	FL	2	0	1	1	0	0
20	Lake and Pond		0	0	0	0	0	0
21	River		0	0	0	0	0	0
22	Estuarine Open Water		0	0	0	0	0	0
30	Short-rotation Cropland	FL	8	0	1	1	0	0
31	Vineyard	FL	2	0	1	1	0	0
32	Orchard and Other Perennial Crops	FL	2	0	1	1	0	0
40	High Producing Exotic Grassland	FL	4	0	1	1	0	0
41	Low Producing Grassland	FL	3	0	1	1	0	0
43	Tall Tussock Grassland	FL	20	0	1	1	0	0
44	Depleted Tussock Grassland	FL	2	0	1	1	0	0
45	Herbaceous Freshwater Vegetation	FL	8	0	1	1	0	0
46	Herbaceous Saline Vegetation	FL	8	0	1	1	0	0
47	Flaxland	FL	10	0	1	1	0	0
50	Fernland	FL	10	0	1	1	0	0
51	Gorse and or Broom	FL	10	0	1	1	0	0
52	Manuka and or Kanuka	FL	25	0	1	1	0	0
53	Matagouri	FL	8	0	1	1	0	0
54	Broadleaved Indigenous Hardwoods	FL1	50	0	-0.0149	1	2.48	0
55	Sub Alpine Shrubland	FL	15	0	1	1	0	0
56	Mixed Exotic Shrubland	FL	10	0	1	1	0	0
57	Grey Scrub	FL	10	0	1	1	0	0
60	Minor Shelterbelts	FL1	50	0	-0.0149	1	2.48	0
61	Major Shelterbelts	FL1	50	0	-0.0149	1	2.48	0
62	Afforestation (not imaged)	FL	3.5	0	1	1	0	0
63	Afforestation (imaged. post LCDB 1)	FL2	30	25	-0.025	-0.034	1	1
64	Forest Harvested	FL2	45	30	-0.025	-0.034	1	1
65	Pine Forest - Open Canopy	FL2	20	20	-0.015	-0.035	1	1
66	Pine Forest - Closed Canopy	FL1	50	0	-0.0149	1	2.48	0
67	Other Exotic Forest	FL1	50	0	-0.0115	1	1	0
68	Deciduous Hardwoods	FL1	15	0	-0.0183	1	1	0
69	Indigenous Forest	FL1	60	0	-0.0149	1	2.48	0
70	Mangrove	FL	5	0	1	1	0	0

Table B2. ROS models and coefficients assigned to LCDB2 vegetation classes. "Class" and "Name" represent original numeric and descriptive values of the land cover types in the LCDB2 database. Different ROS equations are indicated by the designator in column "ROS". Coefficients are shown for each of the ten parameters.

CLASS	NAME	ROS	PP%	P11	P12	P21	P22	P3 1	P32	P4	P5	DoC%
1	Built-up Area		0	0	0	0	0	0	0	0	0	0
2	Urban Parkland/ Open Space	ROS2	100	11400	0	-0.031	1	1.4	0	1	1	60
3	Surface Mine		0	0	0	0	0	0	0	0	0	0
4	Dump	ROS	100	20	0	1	1	0	0	1	1	100
5	Transport Infrastructure		0	0	0	0	0	0	0	0	0	0
10	Coastal Sand and Gravel		0	0	0	0	0	0	0	0	0	0
11	River and Lakeshore Gravel and Rock		0	0	0	0	0	0	0	0	0	0
12	Landslide		0	0	0	0	0	0	0	0	0	0
13	Alpine Gravel and Rock		0	0	0	0	0	0	0	0	0	0
14	Permanent Snow and Ice		0	0	0	0	0	0	0	0	0	0
15	Alpine Grass-/Herbfield	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	100
20	Lake and Pond		0	0	0	0	0	0	0	0	0	0
21	River		0	0	0	0	0	0	0	0	0	0
22	Estuarine Open Water		0	0	0	0	0	0	0	0	0	0
30	Short-rotation Cropland	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	100
31	Vineyard	ROS2	100	11400	0	-0.031	1	1.4	0	1	1	80
32	Orchard and Other Perennial Crops	ROS2	100	11400	0	-0.031	1	1.4	0	1	1	60
40	High Producing Exotic Grassland	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	60
41	Low Producing Grassland	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	80
43	Tall Tussock Grassland	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	100
44	Depleted Tussock Grassland	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	100
45	Herbaceous Freshwater Vegetation	ROS1	100	4920	0	-0.1	1	1.5	0	1	1	100
46	Herbaceous Saline Vegetation	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	100
47	Flaxland	ROS1	100	4920	0	-0.1	1	1.5	0	1	1	100
50	Fernland	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	100
51	Gorse and or Broom	ROS1	100	2460	0	-0.1	1	1.5	0	1	1	100
52	Manuka and or Kanuka	ROS1	100	4920	0	-0.1	1	1.5	0	1	1	100
53	Matagouri	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	80
54	Broadleaved Indigenous Hardwoods	ROS4	50	1800	1800	-0.0697	-0.0232	4	1.6	0.8	50	100
55	Sub Alpine Shrubland	ROS1	100	4920	0	-0.1	1	1.5	0	1	1	100
56	Mixed Exotic Shrubland	ROS1	100	4428	0	-0.1	1	1.5	0	1	1	100
57	Grey Scrub	ROS1	100	2460	0	-0.1	1	1.5	0	1	1	100
60	Minor Shelterbelts	ROS3	100	1800	0	-0.08	1	3	0	0.8	62	100
61	Major Shelterbelts	ROS3	100	1800	0	-0.08	1	3	0	0.8	62	100
62	Afforestation (not imaged)	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	70
63	Afforestation (imaged. post LCDB 1)	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	70
64	Forest Harvested	ROS3	100	4500	0	-0.0297	1	1.3	0	0.75	38	100
65	Pine Forest - Open Canopy	ROS2	100	15000	0	-0.035	1	1.7	0	1	1	70
66	Pine Forest - Closed Canopy	ROS3	100	1800	0	-0.08	1	3	0	0.8	62	100
67	Other Exotic Forest	ROS3	100	1800	0	-0.08	1	3	0	0.8	62	100
68	Deciduous Hardwoods	ROS3	100	1800	0	-0.0232	1	1.6	0	0.9	32	100
69	Indigenous Forest	ROS4	60	1800	1800	-0.0697	-0.0232	4	1.6	0.8	50	100
70	Mangrove	ROS	100	5	0	1	1	0	0	1	1	100

Table B3. Examples of two fuel type classifications for the LCDB2 vegetation classes. "Class" and "Name" represent original numeric and descriptive values of the land cover types in the LCDB2 database. "Detailed" and "Simplified" columns represent our assigned fuel types for map displays.

CLASS	NAME	Detailed	Simplified
1	Built-up Area	Other	Other
2	Urban Parkland/ Open Space	Pasture grassland	Grassland
3	Surface Mine	Other	Other
4	Dump	Dumps	Dumps
5	Transport Infrastructure	Other	Other
10	Coastal Sand and Gravel	Other	Other
11	River and Lakeshore Gravel and Rock	Other	Other
12	Landslide	Other	Other
13	Alpine Gravel and Rock	Other	Other
14	Permanent Snow and Ice	Other	Other
15	Alpine Grass-/Herbfield	Tussock	Grassland
20	Lake and Pond	Waterbodies	Waterbodies
21	River	Waterbodies	Waterbodies
22	Estuarine Open Water	Waterbodies	Waterbodies
30	Short-rotation Cropland	Cropland	Grassland
31	Vineyard	Cropland	Grassland
32	Orchard and Other Perennial Crops	Cropland	Grassland
40	High Producing Exotic Grassland	Pasture grassland	Grassland
41	Low Producing Grassland	Pasture grassland	Grassland
43	Tall Tussock Grassland	Tussock	Grassland
44	Depleted Tussock Grassland	Tussock	Grassland
45	Herbaceous Freshwater Vegetation	Wetland	Scrub/Wetland
46	Herbaceous Saline Vegetation	Wetland	Scrub/Wetland
47	Flaxland	Wetland	Scrub/Wetland
50	Fernland	Scrub	Scrub/Wetland
51	Gorse and or Broom	Scrub	Scrub/Wetland
52	Manuka and or Kanuka	Scrub	Scrub/Wetland
53	Matagouri	Pasture grassland	Grassland
54	Broadleaved Indigenous Hardwoods	Indigenous forest	Forest
55	Sub Alpine Shrubland	Scrub	Scrub/Wetland
56	Mixed Exotic Shrubland	Scrub	Scrub/Wetland
57	Grey Scrub	Scrub	Scrub/Wetland
60	Minor Shelterbelts	Planted forest	Forest
61	Major Shelterbelts	Planted forest	Forest
62	Afforestation (not imaged)	Planted forest	Forest
63	Afforestation (imaged, post LCDB 1)	Planted forest	Forest
64	Forest Harvested	Planted forest	Forest
65	Pine Forest - Open Canopy	Planted forest	Forest
66	Pine Forest - Closed Canopy	Planted forest	Forest
67	Other Exotic Forest	Planted forest	Forest
68	Deciduous Hardwoods	Deciduous hardwood	Forest
69	Indigenous Forest	Indigenous forest	Forest
70	Mangrove	Mangrove	Scrub/Wetland