METHODS FOR THE PRIORITISATION OF WILDING CONIFER SITES ACROSS NEW ZEALAND





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Contract Report No. 3754a

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Project Team:

Kelvin Lloyd - Project management, report author Des Smith - Modelling and analysis Steve Rate - Updating of site data Richard Gillies - Updating of site data Roger Bawden - GIS mapping and analyses

Prepared for: Ministry for Primary Industries Pastoral House 25 The Terrace Wellington

HEAD OFFICE: 99 SALA STREET, P.O. BOX 7137, TE NGAE, ROTORUA Ph 07-343-9017; Fax 07-343-9018, email ecology@wildlands.co.nz, www.wildlands.co.nz

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Reviewed and approved for release by:

[signed]

W.B. Shaw Director/Principal Ecologist Wildland Consultants Ltd



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1. INTRODUCTION

The Ministry for Primary Industries (MPI) recently led the development of the New Zealand Wilding Conifer Management Strategy 2015-2030 (the strategy). Members of the strategy working group provided a range of perspectives, including the Department of Conservation, Land Information New Zealand, New Zealand Defence Force, regional councils, district councils, Scion, New Zealand Forest Owners Association, Federated Farmers, community groups, and MPI.

One action in the strategy is to prioritise wilding conifer infestations, based on the best information available, to inform allocation of funding and control effort. Various steps and criteria are identified in the strategy, as well as suggested cost sharing for collective wilding conifer management (as a basis for negotiation).

MPI commissioned Wildland Consultants Ltd to prepare, in consultation with stakeholders, a nationally prioritised list of wilding conifer control sites across New Zealand. This report describes the methods that were used to prioritise wilding conifer sites and a regional cost-sharing analysis.

2. PROJECT SCOPE

The project scope was to:

- Further develop and agree on the prioritisation criteria identified in the New Zealand Wilding Conifer Management Strategy.
- Identify and collect the information required on each site in order to apply the prioritisation criteria. This built on the inventory of approximately 550 sites that MPI supplied at the start of the project.
- Review and agree on the proposed management objectives for each site.
- Apply the criteria to all sites and agree on the final prioritised list.
- Determine the cost-share implications for Crown/regional councils/land occupiers based on the prioritisation of sites.
- The approach will need to provide MPI with the ability to review and update the prioritisation exercise on a regular basis.

As noted above, this report only addresses methods developed - for this project - for prioritisation of wilding conifer sites across New Zealand.

3. PROJECT METHODS



3.1 Revision of database

The database supplied by MPI was initially reviewed for completeness and clarity of content. A number of issues were identified relating to standardisation of information, and mixing of attributes which needed to be separated for analysis. The database was therefore 'cleaned' to standardise information and to separate attributes, such as the wilding conifer species present at a site.

Further revision of the database was undertaken using new site attributes obtained from field managers and contractors. This included the proportion of spread occupied by each species at each site (e.g. 80% contorta pine - *Pinus contorta*, 20% Douglas fir - *Pseudotsuga menziesii*), and the separation of the 'sparse spread' attribute into 'sparse-coning' and 'sparse non-coning' spread. Considerable work was undertaken to obtain this new information from site contacts.

3.2 Stakeholder consultation

From October 2015 to January 2016 a number of meetings were held jointly with MPI staff and an operational advisory group that included representatives from the farming industry, regional councils, Department of Conservation, Land Information New Zealand, New Zealand Defence Force, and the New Zealand Forest Owners Association.

Early meetings focussed on identification of the attributes that would be used as a basis for site prioritisation. At these meetings, the need was identified to concentrate initial efforts on sparsely-distributed wilding conifer spread. Consultation group members also provided comments on the structure and wording of a questionnaire sent to wilding conifer experts, and identified experts to which it could be sent. At later meetings, the methodology used for site prioritisation was presented to stakeholders, along with the outcomes of prioritisation in terms of the prioritised sites.

The proposed prioritisation methodology, once developed to an advanced state, was also presented to a technical advisory group including staff from Landcare Research, Scion, LINZ, and Department of Conservation, who provided useful comment.

Regular consultation with MPI also occurred through weekly phone conferences in the final few months of the project.

This consultation was invaluable and made a significant contribution to the outputs of the prioritisation project. It is also hoped that the involvement of regular stakeholder consultation will help to ensure that the prioritisation process and outcomes are accepted by stakeholders.

3.3 Prioritisation



A number of attributes were initially proposed as a basis for prioritisation, including spread risk, degree of likely invasion, impacts on values, levels of existing support, cost, and probability of success. Stakeholder discussion resulted in impacts on values not being included as a prioritisation attribute. Values include environmental, landscape, social, and economic disciplines, for which spatial information at a national scale is often lacking or insufficient, and it is also difficult to rank values across disciplines. Level of support, cost, and probability of success are all related. Level of support influences the cost of a control programme, and these attributes also influence the likelihood of success. In addition, level of support is a categorical rather than a continuous variate, reducing its utility for modelling. Level of support, cost, and probability of success are probably best used as filters to further prioritise sites that have been prioritised on biological attributes, such as spread risk and vulnerability. For these reasons, the prioritisation focussed on the invasiveness of the wilding conifers present, and the vulnerability of the surrounding landscape to wilding conifer invasion. The prioritisation process is described more fully in Section 6 below.

4. WILDING CONIFER SITE DATABASE

4.1 Fields

The 30 fields in the wilding conifer site database supplied by MPI are listed in Appendix 1. A considerable number of new fields were added to the database as part of this project, including a basis for the potential merging of sites that were close together, provision of species-specific categories for all species listed as being present at sites, automated checks to ensure that proportional data have been correctly entered, division of the sparse category into coning and non-coning subcategories, standardised fields for siting, downwind land use, and downwind vegetation, and fields for calculation of cost shares, cost-effectiveness, invasiveness, vulnerability, and risk scores for each site.

4.2 Merging of sites

A number of sites were either located at the same point, or were close together. In particular, information for a large number of relatively small sites was provided in the Queenstown area. As sites were the basis for the assessment of risk and costeffectiveness, many adjacent sites infested by the same conifer species and with similarly vulnerable surrounding landscapes were merged to reduce 'spatial duplication' of risk scores.

4.3 Wilding conifers

Eighteen conifer species are recorded in the wilding conifer site database (Table 1). Of these, contorta pine is present at the most sites, followed by Douglas fir and radiata pine (*Pinus radiata*), which are all widely distributed. *Pinus nigra* and larch (*Larix decidua*) are present at a moderate number of sites, while all other conifer species occur relatively infrequently at sites.

Non-coniferous tree species recorded in the database include rowan (*Sorbus aucuparia*; four sites), silver birch (*Betula pendula*; one site), Australian beech (one site), eucalyptus (*Eucalyptus* sp.; three sites), willow (*Salix* sp.; five sites), hawthorn (*Crataegus monogyna*; one site), and poplar (*Populus* sp.; two sites). Non-coniferous tree species are outside the scope of this prioritisation project, but were separated out in the amended site database.

Species/Taxon	Common Name	Number of Sites
Araucaria heterophylla	Norfolk Island pine	1
Chamaecyparis lawsoniana	Lawson's cypress	1
Cryptomeria japonica	Japanese cedar	3
Cupressus macrocarpa	Macrocarpa	4
Larix decidua	Larch	133
Larix kaempferi	Japanese larch	4
Picea sp.	Spruce	2
Pinus contorta	Contorta, lodgepole pine	255
Pinus ellioti		1
Pinus monticola	Western white pine	3
Pinus mugo	Mountain pine	25
Pinus muricata	Bishop pine	12
Pinus nigra	Black pine, Corsican pine	134
Pinus patula	Patula pine	3
Pinus pinaster	Maritime pine	35
Pinus ponderosa	Ponderosa pine	31
Pinus radiata	Radiata pine	215
Pinus sp. / Pine		6
Pinus sylvestris	Scots pine	57
Pinus strobus	Strobus pine	5
Pseudotsuga menziesii	Douglas fir	252
Unknown		3

Table 1: Entries for wilding conifer species recorded in the wilding conifer site database.

5. EXISTING PRIORITISATION SCHEMES

An existing wilding conifer spread risk calculator was developed by Ledgard (2012). This calculator (DSS1) is site-based and weights five criteria - spreading vigour, palatablility, siting, downwind grazing pressure, and downwind land cover - using a 0-4 scale. Key elements of this scoring system are spreading vigour, which is property of individual species, and downwind land use, which addresses the vulnerability of land to invasion by wilding conifers. These two elements are discussed further below.

5.1 Spreading vigour

Spreading vigour may be thought of as the rate at which an invading conifer forms closed stands in suitable habitat that was previously unoccupied by wilding conifers.

Spreading vigour relates to early reproduction, heavy seed production, and habitat breadth. Thus contorta pine, which reaches significant coning on eight-year-old trees, produces abundant, very light seed, and can occupy a range of habitats, has the most significant spreading vigour of all wilding conifers in New Zealand (Ledgard 2012). This is demonstrated by contorta pine being listed at more (255) wilding conifer control sites than any other species, despite being classified as an Unwanted Organism and being illegal to plant it. Douglas fir and Corsican pine (*Pinus nigra* subsp. *laricio*) also have high spreading vigour and are present at many sites.

Spreading vigour of wilding conifer species present in New Zealand was originally included by Ledgard & Langer (1999) in guidelines for minimising the risk of unwanted spread, and has been subsequently used as the basis for spreading vigour in DSS1 (Ledgard 2012; Table 2).

Weighting	Species
0	Redwoods, Leyland cypresses (Chamaecyparis sp.), cedars and spruces (very
	low risk - no need to proceed further).
1	Radiata (Pinus radiata) and ponderosa (P. ponderosa) pine, Lawson's cypress
	(Chamaecyparis. lawsoniana).
2	Muricata (Pinus muricata) and maritime (P. pinaster) pine and larches (Larix
	spp.).
3	Corsican (<i>Pinus nigra</i>) and mountain/dwarf mountain (<i>P. uncinata/mugo</i>) pine.
4	Douglas-fir (Pseudotsuga menziesii), Scots pine (Pomis sylvestris).
5	Lodgepole/contorta pine (Pinus contorta).

Table 2: Spreading vigour of wilding conifers (from Ledgard 2012).

5.2 Downwind land use

Ledgard (2012) used two aspects of downwind land use: grazing pressure and land cover. In practice, these two aspects are entwined, with high-intensity browse pressure in high producing pasture and cropland, and low to moderate browse pressure on most other vegetated cover classes. Also, while browse pressure can be assessed locally at a site, it isn't possible to map browse pressure nationally. For these reasons, land cover alone is the most informative attribute as an index of the susceptibility of downwind land to wilding conifer invasion and spread.

Ledgard (2012) referred to five classes of land cover (Table 3). These classes cover the general habitats in which wilding conifer spread occurs, but the cover classes are not mapped and do not always relate to land cover database (LCDB) categories. Thus they are difficult to utilise in spatial models and prioritisation frameworks.

Table 3: Landcover classes defined by Ledgard (2012).



Priority	
0	Developed pasture, rank grass, plantation forest (no gaps).
1	Native forest, shrubland/tussock/grassland with a continuous and heavy vegetation cover.
2	Forest/shrubland/tussock/grassland with few gaps.
3	Open forest and/or scattered patches of dense shrubland/tussock/grassland with many gaps.
4	Open slips/rockland and/or light, low-stature shrubland/tussock/grassland.

McNeill (2008) modelled wilding conifer spread risk in the Canterbury Region, using digital elevation data, LCDB2, and a wilding conifer database. Wind was modelled simply, assuming one direction of wind and simplified rules between wind interaction with terrain features. Land cover classes from LCDB2 were classified into the four Ledgard (2008) categories (Table 4), although there were obvious difficulties in doing so given that the Ledgard (2008) framework placed the same cover classes in different categories depending on condition. Other problems are that the placement of cover classes in some categories does not always have an ecological basis. For example, relatively invasible mixed shrubland is grouped into a relatively low-risk category, while broadleaved indigenous hardwoods, a closed canopy forest category that is not very susceptible to wilding conifer invasion, is grouped into a moderate risk category. Furthermore, flaxland is given a moderately high risk despite being a wetland type that wilding conifers would not easily invade.

Table 4:Amalgamation of LCDB2 cover classes into Ledgard (2008) invasion
vulnerability classes (from McNeill 2008). Invasion risk increases down
the table.

Ledgard (2008) Classes	Matching LCDB2 Classes (McNeill 2008)
Developed pasture, rank grass, closed	Short rotation cropland
canopy forest/scrub, tussock grassland	Orchard, vineyard, or other perennial crop
with a continuous, vigorous permanent	Herbaceous freshwater vegetation
vegetation cover	Herbaceous saline vegetation
	High producing exotic grassland
	Pine forest open canopy
	Pine forest closed canopy
	Afforestation not imaged
	Afforestation imaged
	Forest harvested
	Minor shelterbelts
	Major shelterbelts
	Other exotic forest
	Deciduous hardwoods
	Indigenous forest
	Mangrove
	Mixed exotic shrubland
Open forest, shrub, tussock, grassland	Gorse and/or broom Mānuka
with mostly dense vegetation cover	and/or kānuka
	Matagouri
	Broadleaved indigenous hardwoods

Shrubland, tussock, grassland with a moderate cover	Flaxland Fernland Low producing grassland Grey scrub
	Tall tussock grassland
Open slips/rockland,	Alpine grass/herbfield
shrubland/tussock/grassland with a light	Depleted grassland
vegetation cover	Subalpine shrubland



6. A NEW WILDING CONIFER PRIORITISATION SCHEME

6.1 Requirement for a new approach

While the outputs of the spreading vigour assessment of Ledgard & Langer (1999) are intuitive, a consensus-based and objective alternative framework for the assessment of spreading vigour was sought, with continuous variation (rather than categories), and which could be easily verified and updated. In addition, downwind land use needs to be mappable if it is to be incorporated into a national prioritisation framework. Due these issues, a new approach to prioritising wilding conifer sites was developed. A key to this approach was obtaining expert consensus on attributes of wilding conifer spread, through the use of a questionnaire.

6.2 Questionnaire

The questionnaire asked expert respondents to evaluate the invasiveness of the ten wilding conifer species that are responsible for most wilding spread in New Zealand (c.f. Froude 2011), within different land cover categories. Other conifer species known to be associated with local spread (Webb *et al.* 1988), such as macrocarpa (*Cupressus macrocarpa*), white mountain pine (*Pinus monticola*), and patula pine (*P. patula*), were also evaluated by some experts.

For national prioritisation, the national scale mapping of LCDB cover classes makes it the most suitable tool for defining land uses that vary in susceptibility to wilding conifer spread. Experts were therefore asked to rank the invasiveness of each wilding conifer species against 18 potentially-invasible land cover categories of LCDB4 (Table 5). Land cover categories assessed as not being invasible by wilding conifers (e.g. wetlands, lakes, intensively-used land, permanent snow and ice) were excluded from the questionnaire (Table 5).

Land Cover Classes (LCDB4)					
Included in Questionnaire	Excluded from Questionnaire				
Alpine Grass Herbfield	Dune Shrubland (Chatham Islands)				
Broadleaved Hardwoods	Estuarine open water				
Deciduous Hardwoods	Flaxland				
Depleted Grass	Herbaceous freshwater vegetation				
Exotic Forest	Herbaceous saline vegetation				
Fernland	High producing exotic grassland				
Forest - Harvested	Lake or pond				
Gorse and Broom	Mangrove				
Gravel or Rock	Orchard, vineyard, or other perennial crop				
Indigenous Forest	Peat shrubland (Chatham Island)				
Landslide	Permanent snow and ice				
Low Producing Grass	River				
Manuka and Kanuka	Sand or gravel				

 Table 5:
 Land cover classes included and excluded from the questionnaire.



	r	
Matagouri or Grey Scrub	Short-rotation cropland	
Mixed Exotic Shrub	Surface mine or dump	
Sand or Gravel	Transport infrastructure	The
Sub Alpine Shrubland	Urban parkland/open space	The
Tall Tussock Grass		

questionnaire included a matrix where the invasiveness of each wilding conifer species was assigned a 0-100 score by respondents in each invasible LCDB4 cover class, with zero corresponding to no invasive capability, and 100 corresponding to the highest invasive capability (Table 6). Co-variates that respondents were asked to complete included years of experience, regions where experience was gained, and predominant role (classified as scientist, manager, or operational).

A total of 26 responses to questionnaires were received, mostly from operational staff and managers, but with six people with a scientific background also responding (Appendix 2). Contorta pine and radiata pine were ranked by all respondents, and Douglas fir by all but one. Black pine (*Pinus nigra*), Scots pine (*P. sylvestris*), ponderosa pine (*P. ponderosa*), mountain pine (*P. mugo*), and European larch (*Larix*)



decidua) were ranked by 13-17 respondents. Relatively few respondents were familiar with wilding spread of maritime pine (*Pinus pinaster*; five responses), bishop pine (*P. muricata*; three responses), macrocarpa (two responses), spruce (*Picea abies*; two responses), or white mountain pine (one response).

Analysis of the questionnaire data provided a transparent, expert consensus-based rating of the spreading vigour of each wilding conifer species or group of species, in different land cover categories, which was used to model spread risk. Wilding conifer species were analysed separately using linear mixed-effects models, with the respondents being a random effect. The predictive strength of land cover type was assessed against the identity of experts. For most species, land cover type was the strongest predictor. The models were then used to predict relative risk scores for each species in each land cover type.

The outcome was a points-based system where higher points indicate greater spread risk or susceptibility to invasion. Previous assessments of spread risk have not been subject to expert consensus, and are generalised across all habitats.

Contorta pine (mean modelled ranking of 41) and Douglas fir (37) were ranked as having very high invasiveness, while Scots pine (25) and black pine (24) had high invasiveness (Table 6). European larch (18) and white mountain pine (16) were ranked as having moderate invasiveness. Ponderosa pine, radiata pine, mountain pine, maritime pine, spruce, bishop pine, and macrocarpa were assessed as having relatively low invasiveness (9-13). These mean modelled rankings apply across all habitats

Tall tussock grassland (mean modelled vulnerability of 36), depleted grassland (33) and low-producing exotic grassland (32) were assessed as being very highly vulnerable to wilding conifer invasion (Table 6), while subalpine shrubland, landslide, mānuka or kānuka, fernland, and gravel or rock were assessed as having high vulnerability (mean modelled vulnerability of 21-29). Sand or gravel, alpine grass/herbfield, gorse and broom, matagouri or grey scrub, mixed exotic shrubland, and harvested forest were assessed as having moderate vulnerability (12-19), while forest cover classes (indigenous forest, exotic forest, broadleaved hardwoods, and deciduous hardwoods) were assessed as having relatively low vulnerability (3-7) to invasion by exotic conifers. These modelled rankings apply across all wilding conifer species.



Table 6:Mean modelled expert scores of wilding conifer invasiveness within land cover (LCDB4) categories.

LCDB4 Category	Pinus contorta	Pinus monticola	Pinus mugo	Pinus muricata	Pinus nigra	Pinus pinaster	Pinus radiata	Pinus ponderosa	Pinus sylvestris	Psuedotsuga menziesii	Cupressus macrocarpa	Larix decidua	Means (LCDB)
Alpine Grass Herbfield	64	0	37	1	27	7	8	7	36	45	0	17	19
Broadleaved Hardwoods	7	8	1	4	5	11	6	4	0	17	0	3	5
Deciduous Hardwoods	7	3	1	1	4	3	3	2	4	12	0	3	3
Depleted Grass	82	20	24	11	6	15	27	23	60	61	10	45	31
Exotic Forest	9	0	1	1	4	3	6	2	4	11	0	3	3
Fernland	22	35	2	16	12	8	8	4	1	27	50	8	19
Forest – Harvested	27	30	1	9	10	5	38	2	7	39	0	4	13
Gorse and Broom	29	30	3	9	22	21	16	11	3	29	1	16	15
Gravel or Rock	57	15	31	6	27	11	12	5	23	37	0	22	19
Indigenous Forest	10	5	1	2	5	8	4	2	4	37	5	4	7
Landslide	51	55	31	32	31	29	17	4	30	46	0	21	27
Low Producing Grassland	75	15	24	9	54	14	22	26	52	59	5	40	31
Manuka and Kanuka	43	30	4	20	20	26	15	14	13	52	10	8	20
Matagouri or Grey Scrub	47	5	10	2	31	5	9	15	33	46	0	30	18
Mixed Exotic Shrub	28	5	3	2	23	6	12	15	19	36	30	20	18
Sand or Gravel	39	15	2	6	25	9	12	3	17	26	0	10	12
Sub Alpine Shrubland	70	0	34	1	36	9	8	11	53	51	5	30	24
Tall Tussock Grassland	73	10	35	6	54	13	14	24	56	61	50	38	37
Means (conifers)	41	16	14	8	22	11	13	10	23	38	9	18	



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6.3 Invasiveness scores

The invasiveness score of each wilding conifer species at a site was calculated by multiplying the proportion of spread occupied by a wilding conifer species at a site by the modelled invasiveness rating of the species (Table 7). Proportion of spread for different species at a site was provided in the site database, and comprises 'best estimate' values contributed by site contacts, rather than counted or measured data. Proportion of spread was also integrated across all classes of wilding tree age and density at a site, including both coning and currently non-coning trees, and could change over time at a site. However, this is useful information with which to generate short term priorities based on current site information.

Where just one wilding conifer species was present at a site, the species invasiveness score is the same as the site invasiveness score (Table 7). Where more than one wilding conifer species was present at a site, the sum of individual species invasiveness scores was used to derive the site invasiveness score (Table 7).

Site	Species	Proportion (%)	Species Scores	Site Invasiveness Score (as fraction)
Rangipo North	Contorta pine	100	100 x 41 = 4,100	0.41
Mid Dome	Contorta pine	97.5	97.5 x 41 = 3,998	3,998 + 0.0028 +
	Mountain pine	2	2 x 14 = 28	0.0019 = 0.40
	Douglas fir	0.5	0.5 x 38 = 19	
Roaring Meg	Douglas fir	100	100 x 38 = 3,800	0.38
Cecil Peak	Douglas fir	65	65 x 38 = 2,405	0.2405 + 0.033 +
	Black pine	15	15 x 22 = 330	0.0345 + 0.009 =
	Scots pine	15	15 x 23 = 345	0.32
	Larch	5	5 x 18 = 90	
Hawkdun	Contorta pine	10	10 x 41 = 410	0.041 + 0.132 +
Range	Black pine	60	60 x 22 = 1,320	0.013 + 0.018
	Radiata pine	10	10 x 13 = 130	+0.038 = 0.20
	Larch	10	10 x 18 =180	
	Douglas fir	10	10 x 38 = 380	
Rangitoto	Radiata pine	97 3	97 x 13 = 1,261	0.1261 + 0.0033 =
Island	Maritime pine		3 x 11 = 33	0.13

 Table 7:
 A selection of wilding conifer invasiveness scores for different sites.

Table 7 shows that among the sites used as examples, the Rangipo North site has the highest invasiveness score, because contorta pine, the most invasive species, is the only species present. The Mid Dome site is not far behind as wilding conifer spread there is dominated by contorta pine. The Roaring Meg site has slightly lower invasiveness as Douglas fir, the second-most invasive species, is dominant at that site. Sites such as Cecil Peak and the Hawkdun Range, where Douglas fir and black pine are common wilding conifers among others, score relatively highly, whereas the Rangitoto Island site, where the moderately invasive radiata pine and maritime pine are present, has a relatively low invasiveness score.

6.4 Vulnerability scores

Vulnerability of land around each site was evaluated for areas within 20 kilometres of the site coordinates supplied. The area of each LCDB cover class within these areas was first divided by the site buffer area, and then multiplied by its wilding _____vulnerability score, expressed as a fraction (Table 8). The products of area \times vulnerability risk for each cover class were summed to give an overall value for the site (Table 8), which was also expressed as a fraction.

Table 8 shows that the Roaring Meg site has higher vulnerability than the Rangipo North and Mid Dome sites. At Roaring Meg, large areas of readily-invasible low producing exotic grassland and tall tussock grassland are mostly responsible for the high vulnerability score. At the Rangipo North site, areas of tall tussock grassland, subalpine shrubland, and gravel or rock contribute mostly to the vulnerability score. At Mid Dome, areas of low producing exotic grassland and tall tussock grassland contribute most to the vulnerability score, but are not as extensive as at the other two sites. Mid Dome's lower vulnerability at the 20 kilometre buffer radius is because there are large amounts of high producing exotic grassland and indigenous forest within the buffer area, which have low vulnerability to wilding conifer invasion.

Site	Land Cover Type	Cover Type Area/ Site Buffer Area	Vulnerability (from questionnaire)	Risk Score (Cover Type Area Fraction
	Deciduous hardwoods	0.007	0.03	0.0002
	Depleted grassland	0.032	0.31	0.0099
	Exotic forest	0.003	0.03	0.0001
	Fernland	0.001	0.19	0.0002
	Forest harvested	0.001	0.13	0.0001
	Gorse and broom	0.001	0.15	0.0002
	Gravel or rock	0.010	0.19	0.0019
Roaring Mea	Indigenous Forest	0.001	0.07	0.0001
Roaning meg	Landslide	0.001	0.27	0.0003
	Low producing exotic grassland	0.389	0.31	0.1206
	Mānuka and kānuka	0.009	0.20	0.0018
	Matagouri or grey scrub	0.007	0.18	0.0013
	Mixed exotic shrubland	0.087	0.18	0.0157
	Subalpine shrubland	0.001	0.24	0.0002
	Tall tussock grassland	0.358	0.37	0.1325
Overall site v	ulnerability score (sum of ind	ividual risk so	ores)	0.29
	Alpine grassland/herbfield	0.036	0.19	0.0068

Table 8:Site vulnerability scores for the Roaring Meg, Rangipo North, and MidDome sites, based on a 20 km buffer radius.



	Broadleaved indigenous hardwoods	0.003	0.05	0.0002
	Depleted grassland	0.032	0.31	0.0099
	Exotic forest	0.055	0.03	0.0017
	Fernland	0.001	0.19	0.0002
	Forest harvested	0.017	0.13	0.0022
	Gorse and broom	0.001	0.15	0.0002
	Gravel or rock	0.134	0.19	0.0255
	Indigenous Forest	0.227	0.07	0.0159
Rangipo	Low producing exotic	0.007	0.31	0.0022
North	grassland			
Site	Land Cover Type	Cover Type Area/ Site Buffer Area	Vulnerability (from questionnaire)	Risk Score (Cover Type Area Fraction □ Vulnerability)
	Mānuka and kānuka	0.076	0.20	0.0152
	Matagouri or grey scrub	0.001	0.18	0.0002
	Mixed exotic shrubland	0.003	0.18	0.0005
	Subalpine shrubland	0.198	0.24	0.0475
	Tall tussock grassland	0.180	0.37	0.0667
Overall site v	ulnerability score (sum of ind	ividual risk so	ores)	0.19
	Alpine grassland/herbfield	0.001	0.19	0.0002
	Broadleaved indigenous hardwoods	0.003	0.05	0.0002
	Deciduous hardwoods	0.007	0.03	0.0002
	Exotic forest	0.023	0.03	0.0007
	Fernland	0.011	0.19	0.0021
	Forest harvested	0.003	0.13	0.0004
	Gorse and broom	0.006	0.15	0.0009
Mid Domo	Gravel or rock	0.025	0.19	0.0048
Mid Dome	Indigenous Forest	0.127	0.07	0.0089
	Landslide	0.001	0.27	0.0001
	Low producing exotic	0.226	0.31	0.0701
	grassland			
	Mānuka and kānuka	0.029	0.20	0.0058
	Matagouri or grey scrub	0.007	0.18	0.0013
	Mixed exotic shrubland	0.009	0.18	0.0016
	Subalpine shrubland	0.003	0.24	0.0007
	Tall tussock grassland	0.163	0.37	0.0603

6.5 National scale vulnerability

Vulnerability scores for LCDB cover types can be used to map vulnerability nationally (Figures 1a and 1b).

On this basis, 4.1 million hectares of mainland New Zealand has very high vulnerability to wilding conifer invasion, and a further 2.9 million hectares has high vulnerability (Table 9). Across all categories, 16.8 million hectares of land has some degree of vulnerability to wilding conifer invasion.

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 Table 9:
 Extent of vulnerable land cover on a national basis.



Land Cover Type	Vulnerability Scores (from Questionnaire)	Vulnerability Category	Area Occupied (1,000 ha)
Alpine grassland/herbfield	19	Moderate	229
Broadleaved indigenous hardwoods	5	Low	656
Deciduous hardwoods	3	Low	96
Depleted grassland	31	Very High	173
Exotic forest	3	Low	1,823
Fernland	19	Moderate	72
Forest harvested	13	Moderate	222
Gorse and broom	15	Moderate	205
Gravel or rock	19	Moderate	873
Indigenous Forest	7	Low	6,308
Landslide	27	High	22
Low producing exotic grassland	31	Very High	1,606
Mānuka and kānuka	20	High	1,173
Matagouri or grey scrub	18	Moderate	112
Mixed exotic shrubland	18	Moderate	50
Sand or gravel	12	Moderate	44
Subalpine shrubland	24	High	433
Tall tussock grassland	37	Very High	2,337
Total Area			16,797

7. LIMITATIONS AND ASSUMPTIONS

A number of limitations and assumptions have affected this prioritisation project, as discussed below.

7.1 Data limitations

As much of the input data came from a spreadsheet compiled from multiple sources, data in the spreadsheet were not easily verifiable, and an assumption was generally made that all supplied data were correct at time the data was supplied. What may have changed, is that the data may no longer be up-to-date due to ongoing management of sites since information was contributed to the database.

7.2 Site location information

In some cases, GPS coordinates were inserted by Wildlands staff in instances where no GPS coordinates were provided, and where the site location was obvious or verifiable from other sources. GPS coordinates that denote site locations influence the orientation of the buffer that was used to determine site vulnerability, but this would mostly affect outlying land covers due to the large buffer size used. For large sites, a point location and buffer may not adequately represent the variation present across the site.



7.3 Lack of data

Prioritisation of sites was hampered by data missing for many sites. These were gradually whittled down through correspondence with site contacts, but some data were not obtained in time for analysis. This includes a number of sites for which no information was provided on the wilding conifer species present. Similarly, where no GPS coordinates were supplied or could be estimated, it was not possible to assess land cover types in buffer areas. These sites where species or site location information was missing consequently had risk scores of zero and should be treated as not assessed.

7.4 Infestation size

Infestation size was not taken into account when generating the risk scores as, in the absence of a nationally-consistent standard for reporting the extent and density of wilding conifer spread, the data supplied is likely to vary considerably in quality. Also, the extent data provided is at the level of the affected area, and does not provide information on the distribution or density of individual species.

7.5 Delineation of sites

A large number of sites are in the database, but sites were delineated by the site contacts who provided the information, thus there was no standard way in which this was done. Some contacts have split large sites into many smaller ones, while others have combined several smaller sites into large sites. The large number of sites in the Queenstown area is notable, where detailed planning for wilding conifer control has resulted in the demarcation of numerous, relatively small management units, whereas in other cases elsewhere in New Zealand, very large sites have been listed as single entities up to 55,000 ha in extent. The size of a site has an influence on the costs of wilding conifer control.

7.6 Site buffers

Circular site buffers were used in the land vulnerability analyses, and these took no account of predominant wind directions or topographic features that would influence wilding conifer spread. As such, the vulnerability of the surrounding landscape may have been over-estimated at some sites.

7.7 Values affected

Importantly, this prioritisation exercise does not address the status or kinds of values that are potentially affected by wilding conifer spread. It is assumed that some kind of value - whether economic, landscape, or conservation - would be affected by all instances of wilding conifer spread, but the degree of this is not known.



8. MANAGEMENT

8.1 Operational management priorities

At priority sites, the overriding priority of wilding conifer management should be to reduce the extent of the area that has been invaded by wilding conifers. This can be done most easily by controlling sparsely-distributed wilding conifers, especially if they have not reached coning stage, and preventing them from forming more dense stands. As the area infested by wilding conifers shrinks, more resources can then be devoted to controlling the sources of wilding spread. Sources that are associated with the greatest spread risk should be controlled first. Isolated sites should also be given higher priority.

Regional prioritisation and prioritisation within management areas can be implemented in the same way. It may be appropriate for some regions to consider the eradication of sources of wilding spread at an earlier stage than others, depending on the extent of sparsely-distributed wilding trees in each region.

For a given amount of funding resource, funding could be allocated to three primary work streams:

- Sites with large areas of sparse non-coning high spread risk species. Allocate a significant portion of overall funding to these sites. Control of these areas will significantly reduce the total area infested, and after control these sites can move to a surveillance framework with handback to the land manager.
- The middle ground. Sites with sparse but coning high risk species over large areas. Allocate a significant proportion of the remaining resource to these areas. Control will also significantly reduce the total area infested. After initial control, conifer regeneration will require further control before the regenerating individuals form cones.
- Sites with mature wilding conifers in all spread risk categories that are sources of significant wilding spread and have large invasible areas. Allocate the remaining resource to these areas, with priority given to demonstrated take-off sites. Control of these areas will significantly reduce the degree of further wilding spread.

As the first two work streams are dealt with, proportionally more resource can be devoted to the third.

Sites with mature wilding conifers that are sources of significant spread can be prioritised according to spread risk, take-off sites, and cost-effectiveness. Costeffectiveness can be calculated as the area of trees controlled divided by the cost of control. Where a number of sites are associated with high spread risk, further prioritisation can be made by first undertaking control at those that contain known take-off sites for wilding conifer spread.

8.2 Management objectives



Management objectives specified in the New Zealand Wilding Conifer Strategy (Table 10) are somewhat problematic. For example the objectives have a degree of overlap, with 'containment' featuring in three of the four categories. In addition, the criteria are not consistent between objectives, and some criteria are vague and open to different interpretations.

Objective	Criteria
Exclusion	Zero density, high value of land's current state, cost-effective to exclude, risk of invasion.
Eradication/	Ability to remove all individuals, low-risk of reinvasion, ability to recover
Containment	site to desired outcome, an area which benefits.
Progressive	Defendable boundaries, feasible to remove sources or stop further
containment	spread, long term funding for knockdown and ongoing maintenance.
Containment/	Integrated pest management outcomes, externality impacts, widely
Sustained control	distributed, long term funding commitment, occupies almost all suitable
	habitat.

Table 10: Management objectives provided in the New Zealand Wilding Conifer Management Strategy 2015-2030.

Revised terminology for objectives, and five criteria that can be used to determine which objective is most appropriate for a site are provided in Table 11. As there is no consistent national-scale information on the values affected, and reinvasion risk and restoration potential depend on site context, determination of objectives for sites is best done at a local or regional basis when the above information becomes available.

Table 11: Management objectives, criteria, and actions suggested for wilding conifer management in New Zealand.

	Criteria					A	Actions	
Objective	Density	Site Values	Vulnerability of Surroundings	Restoration Potential	Reinvasion Risk	Remove Sources	Proposed Methods	
Exclusion	Zero	High	High	Not required	Low	Yes	Surveillance and follow-up.	
Eradication	Low- Mod	High	High	High	Low	Yes	Knockdown and intensive follow-up.	
Progressive control	Mod- High	Mod	Mod-High	Mod-High	Moderate	Yes, over time	Knockdown and ongoing control.	
Containment	High	Low	Mod-High	Low	High	No	Boundary control until resources allow to move to a higher category.	

9. COST SHARING



For the purposes of determining cost sharing according to the framework in Appendix 3 of the New Zealand Wilding Conifer Strategy, two major assumptions have been made:

- GPS coordinates supplied in the site database can be applied to accurately determine ownership of the site.
- All of the sites are legacy (post-RMA 1991) plantings and wildings.

Ownership status of sites was determined by assessing all conservation land and pastoral leases as public land, and assuming that the remainder is private land. This is not likely to be a wholly accurate split, but for the wild areas in which wilding conifers are present, should be sufficiently accurate. More problematic is that in practice, many sites are likely to cover a mix of public and private land, and some sites are likely to include wildings sourced from post-RMA plantings. For these reasons, the cost sharing calculated in this section should be viewed as 'ballpark costs', with more accurate cost share calculations done when better information was available.

As discussed above, the potential costs of wilding control at each site were obtained from two estimates: estimates of five-year control costs provided by site contacts and area-based control costs. Cost shares were determined for both cost estimates.

The cost-sharing methodology was taken from Appendix 3 of the New Zealand Wilding Conifer Strategy. It was assumed that all sites were affected by legacy plantings. This resulted in two sets of cost shares divided between site landholders, central government, regional government, and adjacent landholders. Cost shares for regional government are listed in Table 12.

Decien	Cost Share (\$)			
Region	Costs Estimated by Contacts	Costs Estimated per Area		
Northland	77,200	179,463		
Auckland	14,000	6,900		
Waikato	621,175	1,480,378		
Bay of Plenty	780,700	920,787		
Hawkes Bay	2,638,200	422,098		
Gisborne	No data	12,523		
Chatham Island	11,200	12		
Taranaki	No sites	No sites		
Horizons	624,243	2,458,966		
Wellington	94,900	105,348		
Tasman	805,292	1,050,529		
Nelson	145,000	83,910		
Marlborough	3,673,278	18,831,769		
Canterbury	4,781,257	27,800,400		
Otago	2,871,990	6,491,515		
Southland	2,458,000	628,246		

Table 12: Regional government cost sharing for control based on two cost scenarios - estimates of five year control costs provided by site contacts and areabased control costs - and the control costs for all sites



West Coast	32,000	30,930
TOTALS	19,662,435	64,240,714

Figures in Table 12 show that the wilding conifer problem, based on relative costs, is predominantly associated with six regions: Hawkes Bay, Horizons, Marlborough, Canterbury, Otago, and Southland. Three other regions also incur significant costs: Waikato, Bay of Plenty, and Tasman.

Notably, the area-based costs are significantly greater (c.\$64M) than those estimated by site contacts (c.\$20M). Possibly this is due to control of sparsely-distributed conifers being cheaper than \$15 per ha for very sparse but extensive infestations in Marlborough, Canterbury, and Otago.

When estimated areas of dense and sparse wilding conifer spread are summed for each region, the reasons for the cost differences in Table 12 become clear. The six regions that comprise the bulk of the control costs are generally those that have large amounts of sparse and dense wilding conifer spread. Southland is something of an exception, in that it has a relatively low amount of dense spread, and a moderate amount of sparse spread (Table 13). What Southland does have, is a significant infestation of contorta pine, the most invasive species, at Mid Dome, where control costs are high.

		Estimated Area of Wilding Conif Spread (ha)	
Island	Council Region	Dense Spread	Sparse Spread
	Auckland	0	2,550
	Bay of Plenty	1,923	36,949
	Chatham Island	0	4
	Gisborne	20	1,505
North Island	Horizons	4,484	112,324
	Northland	447	221
	Waikato	2,192	116,836
	Wellington	180	10,828
	Hawkes Bay	6,201	193,332
North Is Total		15,447	474,549
	Canterbury	53,095	652,057
Courth Johnson	Marlborough	41,399	355,258
South Island	Nelson	0	10
	Otago	11,685	283,961

Table 13: Estimated areas of dense and sparse wilding conifer spread within Regional Council boundaries.



	Southland	755	41,433
	Tasman	1,807	85,859
	West Coast	50	300
South Is Total		108,792	1,418,878
Grand Total		124,239	1,893,427

10. CONCLUSION

A new, expert consensus-based wilding conifer control site prioritisation framework has been developed, incorporating the invasiveness of wilding conifer species, and the vulnerability of different land covers. A key advance in this framework is national mapping of the vulnerability of different land cover types, which shows that much of the eastern South Island is highly vulnerable to wilding conifer invasion. The framework is also transparent and has been built on the consensus of experts involved in wilding conifer management. Cost and cost-effectiveness are not taken into account in the framework, and are best used as filters to select from a list of sites that are prioritised according to invasiveness and vulnerability. Values are not incorporated into the framework but this could easily be done if values were to be mapped nationally.

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REFERENCES

Froude V.A. 2011: Wilding conifers in New Zealand: beyond the status report. Report prepared for the Ministry of Agriculture and Forestry.

Ledgard N.J. 2012: DSS 1. Calculating wilding spread risk from new plantings. Version_07011; Issue date: June 2012. Available at: http://www.wildingconifers.org.nz/images/stories/wilding/Articles/DSSs1&2_NES%2 0version%2007011.pdf.



- Ledgard N.J. and Langer E.R. 1999: Wilding prevention guidelines. New Zealand Forest Research Institute Ltd, Christchurch.
- McNeill 2008: Wilding conifer risk mapping in the Canterbury Region; a modelling approach. Landcare Research Contract Report LC0809/000.
- Webb C.J, Sykes W.R., and Garnock-Jones P.J. 1988: Flora of New Zealand, Volume IV. Botany Division, DSIR, Christchurch.

APPENDIX 1

FIELDS IN THE WILDING CONIFER SITE DATABASE

Field	Notes			
ld	Sequential site numbers 1-563 (site 326 missing)			
Reviewed				
Island	North, South (smaller islands included in mainland)			
Group	Mixture of DOC offices, Regional and District councils, LINZ			
Site name_original	Non-unique site name e.g. Arthurs Point, Waitaanga, Walter Peak			
Contact person	One contact, listed person sometimes refers to someone else			
Location (GPS or NZTM	Incomplete, mixture of formats, some coordinates incorrect Grid)			
Site name_sub	Non-unique site name e.g. Arthurs Point, Waitaanga, Walter Peak			
Region	Mixture of regions, districts, councils, quadrants of North and South islands			
Sub region	Incomplete. 8 central NI sub regions only			
Species Conifer	species present. Some other species included at some sites approx ha			
Dense Estimat	ed area of dense wildings (ha), range 0-33,112, plus unknown aprox ha			
Sparse Estimat	ed area of sparse wildings (ha), range 0-72,216, plus unknown			
Proposed				
Management Manager	nent Criteria Approach Objective			
	Exclusion Zero density, high value of land's current state,			
	costeffective to exclude, risk of invasion.			
	Eradication/ Ability to remove all individuals, low-risk of reinvasion,			
	<i>Containment</i> ability to recover site to desired outcome, an area which			
	benefits.			
	Progressive Defendable boundaries feasible to remove sources or			
	containment stop further spread, long term funding for knockdown and			
	ongoing maintenance.			
	Containment / Integrated pest management outcomes.			
	externality Sustained impacts, widely distributed, long term funding			
	control commitment, occupies almost all suitable habitat.			
Approximate cost to achieve control approa	Range \$60-\$8,000,000 ch in 5 year			
period				
Programme	Y, N			
underway				
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Parties involved (list	Community (Iwi)					
all)	Dep	Department of Conservation (DOC)				
	Land	d Information NZ (LINZ)				
	NZ [Defence Force (NZDF)				
	Reg	ional Councils (RC)				
	Terr	Territorial Local Authorities (TLA)				
	Othe	Other (Other)				
Siting						
	а	Sheltered sites, or slopes facing away from strong/prevalent winds.				
	b	Sites partially exposed to strong/prevalent winds (often from N & W - 2000 to 450).				

- c Sites partially exposed to strong/prevalent winds.
- d take off' site i.e. Ridgetops, on or at base of slopes (>10o) or undulating land fully exposed to strong/prevalent winds.

Downwind land use			
	а	Developed pasture/regular mob stocking (sheep) or closed canopy scrub/forest.	
	b	Semi improved (some fertiliser used in past), sheep grazing/ occasional mob stocking.	
	С	Extensive grazing only.	
	d	No grazing.	
Downwind vegetation			
	а	Developed pasture, rank grass, closed canopy forest.	
	b	Shrubland/tussock/grassland with a continuous and heavy vegetation cover.	
	С	Forest/shrubland/tussock/grassland with few gaps.	
	d	Open forest and/or sparse patches of dense shrubland/tussock/ grassland with many gaps.	
	е	Open slips/rockland and/or light, low-stature shrubland/tussock/ grassland.	
Rough estimate of area at risk of invasion	Area	in hectares (range 0-215,000)	
Notes rough estimate of area at risk	Few notes provided (four sites only)		



Types of values at				
risk (list)	Economic (Ec) Maintenance of specific land-use productivity, direct to human livelihood, minimisation of direct off-site effects.			
	Environmental	Biodiversity (protect ecosystem or particular species),		
	(En)	maintenance of current natural resource mix.		
	Social (So)	Maintenance of landscape appearance, social/ community impact.		
Source land (crown private or both)	Land ownership -	crown, private, or both.		
Receiving Land (crown private or both)	Land ownership -	crown, private, or both.		
Source pre or post 1990	Pre, Post			
Other Comments	Wide range of cor etc.	mments on past control, site values, sources of information		
DSS1 Tots	Scores based on DSS1 assessment.			
No Risk	Uncertain what this applies to.			

APPENDIX 2

EXPERTS WHO RESPONDED TO THE WILDING CONIFER QUESTIONNAIRE

Export	Polo	Wilding Conifer Experience		
Expert	Kole	Years	Areas	
Nick Ledgard	Scientist	30	All of New Zealand	
Alan Mark	Scientist	20	Otago, Southland, Canterbury	
Andrew McAlister	Manager	7	Nelson-Marlborough	
Brad Lett	Operations	15	Central North Island	
Clayson Howell	Scientist	8	Otago, Canterbury, Central NI	
Colin Day	Operations	5	Otago, Southland	
Craig Davey	Manager	12	Central North Island	
Dean Turner	Operations	17	Canterbury	
James Kilgour	Operations	8	Canterbury, Nelson/Marlborough	
Graeme Omlo	Manager	35	Nelson/Marlborough	
lan Cox	Operations	25	Nelson/Marlborough	
Jono Underwood	Manager	6	Nelson/Marlborough	
Larry Burrows	Scientist	30	All of New Zealand	



Leith Rhynd	Operations	28	Central North Island
Paul Hondelink	Operations	40	Otago
Patrik Eschenmoser	Operations	8	Otago
Pete Raal	Operations	15	All of New Zealand
Peter Willsman	Manager	8	Otago, Southland
Ray Goldring	Manager	6	Canterbury
Richard Bowman	Manager	15	Otago, Southland
Richard Heyward	Operations	2	Otago
Wayne Godfrey	Operations	11	South Island
Willie Shaw	Scientist	30	Otago, Canterbury, Nelson/
			Marlborough, Central NI
Kelvin Lloyd	Scientist	15	South Island
Shane Grayling	Manager	3	Bay of Plenty
Pete Willemse	Manager	14	Southland, Canterbury





Call Free 0508 WILDNZ Ph: +64 7 343 9017 Fax: +64 7 3439018 ecology@wildlands.co.nz 99 Sala Street PO Box 7137, Te Ngae Rotorua 3042, New Zealand Regional Offices located in Auckland, Hamilton, Tauranga, Whakatane, Wellington, Christchurch and Dunedin

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