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**Pastoral Sector Weed Research Strategy**

**Our Vision**

Current and potential future weeds of pastoral farmland in New Zealand are managed long-term cost-effectively using environmentally, socially and culturally acceptable tactics.

AgResearch is a key provider of world-class science supporting pastoral weed management decision-making at all scales from paddock to nation and at all stages of the invasion process.

Pastoral weeds are defined as plant species, typically exotic in origin, that currently, or may in the future, invade pastures and reduce farm profitability.

**Key Sector Challenges**

- Diverse-pasture Herbicide Options
- Weeds in Waterways
- National Weeds Strategy
- Behaviour Change
- Pasture Invasion by Weeds

**Outcomes**

- Improved internal biosecurity
- Increased suite of non-chemical weed control options
- Herbicide resistance evolution understood and controlled
- Weed population biology informs weed management
- Weed control economics informs weed management
- Best practice pastoral weed management adopted
- Effective riparian weed management

**Target Research Areas**

- Weed risk analysis
- Climate and land-use change
- Invasion biology
- Biological control
- Herbicide resistance evolution
- Population dynamics
- Bio-economics

**Research Capability**

- Population dynamics/genetics
- Evolutionary processes
- Plant ecology
- Entomology
- Plant pathology
- Microbial formulation
- Experimentation
- Mathematical modelling
- Economics

**Key Initiatives**

- Strategic Science Investment Fund weeds programme
- MBIE Endeavour Fund Programme proposal
- Sustainable Farming Fund projects
- Grow weed science capability and capacity
- Alignment with internal and external strategies
- Stakeholder engagement
- Co-development of research programmes
- International collaborations
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1. Executive Summary

This document sets out a ten-year Pastoral Weeds Research Strategy as requested by the 2017 ‘Strategic Science Investment Fund’ Investment Committee. It was developed from:

a. A review of key current pastoral weeds research worldwide; especially where there are solid links with AgResearch interests,
b. A summary of existing research capability within AgResearch and New Zealand as a whole,
c. A stakeholder meeting with the pastoral sector that identified key weed management issues,
d. Recommendations as to how the AgResearch capability should be positioned over the next ten years (2018 – 2028)

The strategy contains a vision, identified sector challenges, outcomes sought, research capability needed to deliver to target research areas and some initial key initiatives. Priority outcomes are:

1. Improved internal biosecurity.
2. Increased suite of non-chemical control options.
3. Herbicide resistance evolution understood and controlled.
5. Weed control economics informs and disrupts weed management.
7. Effective riparian weed management.
2. Introduction

The AgResearch pastoral weeds programme, formally known as ‘Undermining Weeds’ and before that ‘Outsmarting weeds’, has been supported through Core funding (now Strategic Science Investment Fund) since 2012. Recently the project was awarded a three year SSIF contract and as part of that process, the Investment Committee required a ten-year ‘Pastoral Weeds Research Strategy’ be developed. The new strategy would update thinking from an industry workshop in 2015 at which biological weed control, thistles and managing herbicide resistance ranked high as issues for the pastoral sector. Specifically, the Investment Committee requested:

1. “An overview of current pastoral weeds research in AgResearch, other organisations in New Zealand and key overseas research initiatives”,

2. “A summary of existing research capability within AgResearch and New Zealand as a whole”,

3. “An overview of the pastoral sector's weed management issues”,

4. “Recommendations as to how the AgResearch capability should be positioned over the next ten years (2018 – 2028)”

For the purpose of this strategy, a ‘pastoral weed’ is defined as a plant (typically an exotic species) that impacts negatively on pastoral farming. Its economic impact may often be through the exclusion of grazing. This occurs mainly with non-palatable species and costs an estimated $1.3 billion lost production value per year (Saunders et al. 2017). This is a conservative estimate of the national aggregate grazing loss due to weeds given that it is based on data available for just 10 weed species while an estimated 187 weed species occur in our pastures (Bourdôt et al. 2007). Many of these species are either not palatable to many classes of livestock and/or are low-producing in terms of digestible dry matter.

In addition to lost grazing, there are costs associated with reduced animal product quality (e.g. pelt and carcase damage, wool contamination, milk taint), animal health and welfare impacts (e.g. poisoning and weed seed penetration of eyes and other body parts) and weed control operations.

Weeds also impact the pastoral sector through yield and product quality losses in forage crops (e.g. maize and fodder beet).

The aim of this strategy is to identify how the AgResearch weed research programme can inform the sustainable management of pastoral sector weeds in New Zealand over the next 10 years. Appropriately positioned (science objectives) and resourced (staff and funding) research that is well aligned to an agreed prioritised list of pastoral industry weed management issues is required.
In developing this strategy, we recognise that weed management decisions occur at a variety of scales (national, regional, industry, farm, paddock etc.) and that the information and understanding required to inform them is therefore also scale-dependent.

We also recognise that most pastoral weeds in New Zealand are invasive aliens that vary widely in their invasion trajectories and their current position along their trajectory. The invasion trajectory is a useful concept at a national scale and may be equally useful at smaller scales of weed management decision-making such as regional, farm, paddock etc.

The invasion trajectory is logistic in shape (Figure 1). It can be divided into four segments defining the status of the weed: ‘absent’ (not known to occur); ‘sleeper’ (locally naturalised with little impact); ‘spreading’ (naturalised in many places but not yet occupying potential range); widespread (occurring throughout the potential range).

The categories represent opportunities to manage a species through ‘exclusion’, ‘eradication’, ‘containment’ or ‘sustained control’ programmes. The Biosecurity Act 1993, its 2012 amendments and the National Policy Direction for Regional Pest Management (Ministry for Primary Industries 2015), require Regional Pest Management Programmes to classify species-led weed management programmes using these four types of management.

A common consideration at all scales of weed management decision-making is that weed control is cost-effective. Whilst this is a legal requirement for weed management under a Regional Pest Management Plan, it is also an important consideration for weed management at the farm scale. In both cases, estimation of the benefits of weed management relies upon a sound understanding of the ecology, and in particular for pastures, the population dynamics of the weed over the long-term.

![Weed Invasion Model](image)

**Figure 1.** Weed invasion model classifying a weed and its management according to the extent to which it has occupied its potential range at the scale of interest.
3. Overview of current pastoral weeds research

3.1. New Zealand

Four research organisations in New Zealand undertake scientific work related to better understanding and managing weeds that invade pastures. These are the two Crown Research Institutes AgResearch and Landcare Research and the two universities, Lincoln and Massey. In total, these four organisations employ approximately 17 scientists with a focus on weeds but less than 50% of them address pastoral weed issues and for most of these, including the AgResearch weed scientists, pastoral weeds research forms only part of their work. Further details are provided in Section 7.

An overview of current weed research, in the context of the 'weed invasion model', as it relates to the pastoral sector in New Zealand, is given in Figure 2 as a series of images from the PowerPoint presentation given by Graeme Bourdôt at the workshop on 20 November 2017.

Starting at the top left, and reading from left to right down the page, it is apparent that current research in New Zealand spans the entire invasion model. Dr Trevor James, AgResearch is working on predicting the plant species that potentially could arrive in New Zealand and invade dairy pastures. This is apparently the only research into pastoral weed species that are not currently in New Zealand (Absent) but are problems overseas. Professor Phil Hulme at the Bio-Protection Centre at Lincoln University works across a wider part of the invasion model space spanning the Sleeper and Spreading phases. He is focussing on learning how contemporary evolution in a weed species, using docks as a model system, may influence its invasion trajectory in New Zealand. Dr Duane Peltzer at Landcare Research, Lincoln, is leading a new research programme that is aiming to explain the invasion of wilding trees in New Zealand as a basis for their improved management. This research contributes to a better understanding of the Spreading phase of the invasion model space. The remainder of the research programmes, those led by Dr Graeme Bourdôt (the AgResearch SSIF pastoral weeds programme), Dr Seona Casonato (Lincoln University), Dr Kerry Harrington (Massey University) and Dr Simon Fowler (Landcare Research) focus on species that are in the Widespread phase of the invasion model space. These species are already widely problematic and economically damaging weeds and some have developed herbicide resistant populations. The research focusses on explaining and predicting the population dynamics of these weeds, their economic impacts and their responses to novel control methods such as insects and plant pathogens as biological control agents, crop competition, mowing, lasers and manual removal. Professor Dave Kelly, School of Biological Sciences, University of Canterbury, is a plant population ecologist. He contributes to the management of weeds in pasture through demographic modelling and through co-supervision of post-grad projects on weeds with AgResearch scientists.

Although these research programmes span the invasion model space, there is apparently a greater focus and research effort on the Widespread phase of the invasion model’s space than at the earlier phases. We consider below, under Recommendations, the extent to which this current weed research focus fits with the Key Issues developed through the Workshop.
Figure 2. An overview of current weed research, in the context of the ‘weed invasion model’, as it relates to the pastoral sector in New Zealand (from industry/science workshop on 20 November 2017).
3.2. Overseas

This section is not an exhaustive global list of organisations that are involved in pastoral weed research. Rather, it provides a summary of the pastoral weed research focus of overseas organisations with which the authors of this document collaborate. It excludes overseas industry bodies, small companies and large multinational companies involved in discovery and development of synthetic and biological herbicides.

**CSIRO – Australia** CSIRO has a long and successful history of using biological control agents as a cornerstone of sustainable management programs for weeds of national significance, such as Paterson's curse and prickly pear. Dr Louise Morin's work with plant pathogens in classical and bioherbicide approaches is well known to us through our connections with the International Bioherbicide Group of which one of us (GWB) was a past President. CSIRO has many active biocontrol projects underway for both temperate and tropical Australian weeds which cause problems in natural, pastoral and agricultural ecosystems. A related initiative is the Cooperative Research Centre for Weed Management which unites several research groups across Australia.

**AAFC - Agriculture and Agri-Food Canada – Saskatoon** This organisation conducts research that supports the commercial development of plant pathogenic fungi and bacteria as bioherbicides and the use of cover crops for weed management. They have recently co-developed and released a bioherbicide product for flat-weeds such as dandelions and Californian thistle in fine turf and are considering how such a weed control product could be developed for pastures. AgResearch is collaborating with scientists at AAFC to develop a bioherbicide for Californian thistle in pastures.

**UU - Uppsala University** Professor Lars Andersson and his students at the Department of Crop Production Ecology, The Swedish University of Agricultural Sciences, conduct research into the ecology and management of weeds of temperate leys and cereal crops. Their research has a strong focus on sustainable, ecologically benign, non-chemical weed management.

**UWA - University of Western Australia** The Australian Herbicide Resistance Initiative (AHRI) is a world leader in herbicide resistance research. Understanding resistance mechanisms and weed seed bank ecology is providing the basis for avoiding and managing resistance. For example, Professor Michael Renton has published computer-based simulation models (e.g. Weed Seed Wizard and PERTH) as aids to growers for managing herbicide resistant weeds. Richard Hobbs (Ecosystem Restoration and Intervention Ecology Research Group) produced a body of work (and trained academics) that look at priority setting for novel-ecosystems, invasive species management, restoration and plant succession.

**CABI - Centre for Agriculture and Biosciences International** CABI (Switzerland) carries out research on classical biocontrol of weeds of European origin, and have provided scientific expertise in relation to biocontrol programmes in NZ (e.g. thistle biocontrol agents). Currently, CABI is investigating the potential for classical biocontrol of 17 different weed species in North America. Current projects with potential relevance to the pastoral sector in NZ include
hawkweeds (*Pilosella* spp.), common tansy (*Tanacetum vulgare*), Oxeye daisy (*Leucanthemum vulgare*) and field bindweed (*Convolvulus arvensis*).

**USDA- United States Department of Agriculture** Dr Frank Forcella, an agronomist with the Agricultural Research Service at Morris, Minnesota, conducts research on cultural (non-herbicide) weed management in crops. His research includes the use of cover crops and the development of alternative technologies such as abrasion weed control.

**CIB - Centre for Invasion Biology.** This South African research institution is headed by David Richardson a preeminent scholar in invasion biology whose publications emphasize plant invasions. Their science aims to provide the understanding necessary to reduce the rate and impacts of biological invasions.

**DIE–ASCR - Department of Invasion Ecology, Academy of Sciences Czech Republic.** Petr Pysek has led several efforts to make invasive plants a priority for research and management in Europe. Weed risk assessments are a particular strength.

**EBD - Estación Biológica de Doñana.** Montserrat Vilà focuses on risk assessment of European invasive species, biotic and abiotic factors affecting invasion success as well their impacts on ecosystem services.

**Penn State - Department of Biology, Pennsylvania State University.** Professor Katriona Shea and her students develop population models for weeds and use these models to explore potential management strategies. We have a shared interest in developing a better understanding of the spread and management of thistles in pastures.
4. Summary of pastoral weeds research capability

4.1. AgResearch

Weeds research capability in AgResearch is at a critically low level (Table 2). This is a result of ongoing losses of science and technical staff since the formation of the CRIs. Funding shortfalls are due to the combined effects of unsuccessful weed management funding proposals and the effects of inflation on SSIF-funded weed research programme.

Ruakura-based capability consists of Trevor James (Scientist, 0.8 FTE), Chris Buddenhagen (recently appointed Post-doc scientist, 1.0 FTE), Claire Dowsett (Technician, 0.8 FTE) and Mike Trolove (Technician, 1.0 FTE); a total of 3.6 FTEs.

Lincoln-based capability consists of Graeme Bourdôt (Principal scientist, 1.0 FTE), Shona Lamoureaux (Scientist, 0.8 FTE), Mike Cripps (Scientist, 1.0 FTE) and Sarah Jackman (Technician, 1.0 FTE); a total of 3.8 FTEs. In addition at Lincoln, the team currently supervises five weed science students (Dilani Kasundara Hettiarachchi, Bethanne Smith, Caitlin Henderson, Aaron Sakala and Jovesa Navukula).

The total annual budget (FY19) required to maintain this team of 4.6 scientists and 2.8 Technicians is $2,355,477. Currently, 52% of this cost is covered by SSIF funds ($1,222,000).

Table 1. Summary of weed research capability in AgResearch for FY18 and FY19. Budget requirement for FY19 assumes all roles are permanent (1.8 Scientist FTE at Ruakura) and $20,000 operating/Scientist FTE).

<table>
<thead>
<tr>
<th></th>
<th>FY17-18</th>
<th>FY18-19</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scientists</td>
<td>Technicians</td>
</tr>
<tr>
<td>Ruakura</td>
<td>0.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Lincoln</td>
<td>2.8</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>3.6</td>
<td>2.8</td>
</tr>
</tbody>
</table>

4.2. Other NZ organisations

MWLR - Landcare Research Weed research capability at Landcare Research consists of Simon Fowler, Ronny Groenteman, Lindsay Smith, Hugh Gourlay, Quentin Paynter, Lynley Hayes (weed biological control) and Duane Peltzer and others (Wilding tree ecology).

LU - Lincoln University Weed research capability at Lincoln University resides in Phil Hulme and Jon Sullivan (weed invasion ecology), Seona Casonato (plant pathogens for weed control) and their post-graduate students (about 6).

MU - Massey University Weed research at Massey University resides in Kerry Harrington and his post-doc researcher, Hossein Ghanizadeh (herbicide resistance).
**Scion** Scientists at Scion are exploring the potential of remote sensing in planation forest weed management.

**DoC - Department of Conservation** Research on strategic weed management approaches in conservation areas, measuring management effectiveness, risk-assessment and weed biology. Often the work emphasizes woody weeds.

**MPI - Ministry for Primary Industries** Weed risk analysis, pathway analysis, incursion response, plant quarantine, border biosecurity.

**BS-UC - Biological Sciences–University of Canterbury** David Kelly has been a leader in population modelling for NZ plants including weeds.

**AERU – Agribusiness and Economics Research Unit** Caroline Saunders and her team at Lincoln have expertise in quantifying the economic effects of weeds and their management in New Zealand.

**NIWA – National Institute of Water and Atmospheric Research** Weeds of fresh water and riparian vegetation.
5. Overview of the pastoral sector’s weed management issues

Pastoral sector weed management issues identified by the industry and science representatives at a workshop, and their grouping into Key Issues, are given along with the workshop methodology, in the Appendix 1. A total of 37 issues were identified by the two groups of participants. Looking at the number of votes given to each of these issues, there is evidently no strong correlation (agreement) between how industry and science perceive their importance. For example, the issue “Sleeper weeds” received 1 industry vote and 8 science votes. By contrast, “Inter-farm weed biosecurity” received 4 and 0 votes respectively. However, when we group these two issues, and the others raised at the workshop that also reflect an underlying concern about the spread of weeds to new places (under the Key Issue, Internal biosecurity), we see a much greater level of agreement between industry and scientist perception with 12 and 22 industry and scientists votes respectively (Appendix 1).

Looking across all 37 issues, we have been able to group them into a set of 8 Key Issues (Table 2). These Key Issues (challenges) are defined as follows:

1. **Internal biosecurity**

   There is widespread concern that New Zealand has many naturalised weedy adventive plant species that have not yet occupied their potential distributions. Identifying these species and predicting their likely future population trajectories is required in order to quantify the risk that they present and make informed and cost-effective decisions about their management.

2. **Herbicide resistance**

   Concern that the pastoral sector will lose currently effective herbicides through evolved resistance in weed populations is at the heart of this issue. Several economically important pastoral weeds in New Zealand, such as giant buttercup and nodding thistle, have already evolved populations that are resistant to the phenoxy herbicides. The recent confirmation that ryegrass populations have evolved resistance to glyphosate in New Zealand, one of the most widely used herbicides in pasture renovation, along with anecdotal evidence of other weedy grasses becoming resistant to other classes of herbicides in forage crops, has fuelled this issue. Its importance is highlighted by the knowledge that effective, alternative modes of action, are unlikely to be developed by the global agrichemical industry and so preserving the efficacy of our existing herbicides is vital.

3. **Alternatives to herbicides**

   Reliance upon chemical herbicides for pastoral weed control is increasingly becoming unsustainable not only because of evolved resistance in weeds, but also because of public health and environmental concerns over herbicide use, increasing industry and market requirements for residue-free farm produce, regulatory constraints on herbicide application practices, fewer new herbicides becoming available, withdrawal of herbicides from the market and the global increase in organic agriculture. As a result, there is a pressing need to develop alternatives to synthetic chemical herbicides. There
is, for example, considerable unexplored potential to utilise natural enemies for ‘biological’ weed control in pastures (Bourdôt & Cripps 2018).

4. **Pasture invasion by weeds**

The need for pastures that persist following sowing and forage crops that are less prone to invasion by, and yield losses due to weeds, are key considerations here. The underpinning idea is that by understanding how weeds invade these systems, the invasions might be prevented resulting in more persistent pastures and higher-yielding forage crops.

5. **Behaviour change**

This Key Issue reflects a perceived need, especially among pastoral industry people, that weed control is too often reactive (after the problem has arisen) rather than proactive (preventing the problem from arising). There’s need for educating pastoral farmers about the economic effects of weeds and the economic benefits accruing from preventative actions.

6. **National weeds strategy**

New Zealand could benefit from having a national strategy on weeds that provides priorities to guide research and weed management investment. For example, Australia has such a strategy ‘The Australian Weeds Strategy’ which provides a national framework for addressing weed issues whilst maintaining the profitability and sustainability of Australia’s primary industries and the reducing the impact of weeds on the environment.


7. **Weeds in waterways**

An on-farm issue that restricts water flow and potentially causes downstream weed infestations in pastures (e.g. alligator weed). In addition, the new requirement for farm environment plans and fenced waterways has created a new dimension to weed management and associated nutrient runoff management.

8. **Diverse-pasture herbicide options**

Pastures sown with a mixture of grasses and nitrogen-fixing legumes have traditionally featured on New Zealand farms. These mixtures provide many hurdles for selective weed control using herbicides that tend to be either grass or broadleaved weed killers. Few herbicide products exist, even today, that can remove grass or broadleaved weeds from a pasture without also damaging either the grass or legume component. This problem has escalated for modern-day pastures that are sown not just with a grass and a legume, but also with chicory, plantain and other broadleaved plants.
These 8 Key Issues fall into three distinct groups regarding their overall importance as perceived by the workshop delegates (Table 2). The first three, ‘Internal biosecurity’, ‘Herbicide resistance’ and ‘Alternatives to herbicides’, were the highest in importance with 83/129 (64%) of the total votes. The next two, ‘Pasture invasion by weeds’ and ‘Behaviour change’ were of lesser importance, receiving 30/129 (23%) of the total votes. The last set of three Key Issues, ‘National weed strategy’, ‘Weeds in waterways’ and ‘Diverse-pasture herbicide options’ were the lowest in importance with 16/129 (12%) of the total votes.

The Key Issues also exhibit another grouping with regard to their perceived importance. The first five were considered of equal importance by industry but fell into three importance groups for the scientists with ‘Internal biosecurity’ being of highest importance followed by ‘Herbicide resistance’ and ‘Alternatives to herbicides’ and then ‘Pasture invasion’ and ‘Behaviour change’.

Table 2. Summary of the results of the Weed Issues workshop held at Lincoln on Monday 20 November 2017. The summary shows the distribution of 129 importance votes (by industry and scientist delegates) among eight high-level Key Issues that were derived by grouping the 37 issues raised and discussed at the workshop (Appendix 1). NB, regional councils provided a written report detailing a 10-year vision and key issues for pastoral weed management (Appendix 3)

<table>
<thead>
<tr>
<th>Key Issue</th>
<th>Votes (industry)</th>
<th>Votes (scientist)</th>
<th>Votes (Total)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal biosecurity</td>
<td>12</td>
<td>22</td>
<td>34</td>
<td>26%</td>
</tr>
<tr>
<td>Herbicide resistance</td>
<td>10</td>
<td>14</td>
<td>24</td>
<td>19%</td>
</tr>
<tr>
<td>Alternatives to herbicides (lacking)</td>
<td>11</td>
<td>14</td>
<td>25</td>
<td>19%</td>
</tr>
<tr>
<td>Pasture invasion by weeds</td>
<td>9</td>
<td>7</td>
<td>16</td>
<td>12%</td>
</tr>
<tr>
<td>Behaviour change (needed)</td>
<td>11</td>
<td>3</td>
<td>14</td>
<td>11%</td>
</tr>
<tr>
<td>National weeds strategy (lacking)</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>5%</td>
</tr>
<tr>
<td>Weeds in waterways</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4%</td>
</tr>
<tr>
<td>Diverse-pasture herbicide options (lacking)</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td>66</td>
<td>129</td>
<td>100%</td>
</tr>
</tbody>
</table>

It is relevant to acknowledge here that the importance assigned to these Key Issues reflects the interests and perceptions of the workshop delegates and that different results may have arisen given a different set of industry and science people. For example, the low importance assigned to ‘Behaviour change’ by the scientists (Table 2) no doubt reflects the fact that there were no social scientists among the 12 scientist delegates. Despite these considerations, the workshop results in Table 2 provide a defendable basis for recommending how AgResearch weed research capability should be positioned over the next ten years. This is discussed in detail in Section 7 below.
6. Strategy

Our strategy for using science to inform the pastoral weed issues identified in the previous section is summarised in the diagram “The AgResearch Pastoral Sector Research Strategy”. The diagram presents the key issues as scientific ‘Challenges’ along with an overall ‘Vision’ for pastoral weed research in AgResearch. At a high level, meeting the sector Challenges will require the realisation of some key intermediate ‘Outcomes’, successful scientific endeavour within a set of relevant ‘Target Research Areas’, availability of the necessary ‘Research Capability’, and a plan detailing ‘Key Initiatives’.

In the following subsections we provide a narrative for the Strategy where we expand on each of its components under Outcomes and Target Research, Alignment and Resourcing.
Our Vision
Current and potential future weeds of pastoral farmland in New Zealand are managed long-term cost-effectively using environmentally, socially and culturally acceptable tactics.

AgResearch is a key provider of world-class science supporting pastoral weed management decision-making at all scales from paddock to nation and at all stages of the invasion process.

Pastoral weeds are defined as plant species, typically exotic in origin, that currently, or may in the future, invade pastures and reduce farm profitability.

Key Sector Challenges
- Diverse-pasture Herbicide Options
- Weeds in Waterways
- National Weeds Strategy
- Behaviour Change
- Pasture Invasion by Weeds
- Internal Biosecurity
- Herbicide Resistance
- Alternatives to Herbicides

Outcomes
- Improved internal biosecurity
- Increased suite of non-chemical weed control options
- Herbicide resistance evolution understood and controlled
- Weed population biology informs weed management
- Weed control economics informs weed management
- Best practice pastoral weed management adopted
- Effective riparian weed management

Target Research Areas
- Weed risk analysis
- Climate and land-use change
- Invasion biology
- Biological control
- Herbicide resistance evolution
- Population dynamics
- Bio-economics

Research Capability
- Population dynamics/genetics
- Evolutionary processes
- Plant ecology
- Entomology
- Plant pathology
- Microbial formulation
- Experimentation
- Mathematical modelling
- Economics

Key Initiatives
- Strategic Science Investment Fund weeds programme
- MBIE Endeavour Fund Programme proposal
- Sustainable Farming Fund projects
- Grow weed science capability and capacity
- Alignment with internal and external strategies
- Stakeholder engagement
- Co-development of research programmes
- International collaborations
6.1. Outcomes and Target Research Areas

Below, the Outcomes sought are given along with the required research, collaborations and stakeholder engagements and funding. To achieve priority outcomes listed here we must engage stakeholders to facilitate innovative weed management at local, regional and national levels.

6.1.1 Improved internal biosecurity

Our research will: 1) Develop risk-assessment and decision-making tools useful for engaged stakeholders at farm, regional and national levels for species already present in NZ but with a limited distribution and for new incursions; 2) develop control methods for selected priority species e.g. high-threat low-incident pests; 3) account for global-change (e.g. climate and land-use changes); 4) Support evidence-based pathway management.

6.1.2 Increased suite of non-chemical control options

Our research will: 1) Help realize the potential benefits of biological control of weeds (Classical and inundative) through understanding relevant biological processes and the associated risks; 2) Develop, test and promote (through stakeholder engagement) disruptive farming cultural practices that reduce weed control costs and environmental impacts of weed control.

6.1.3 Herbicide resistance evolution understood and controlled

Our research will: 1) Develop tools to predict (and avoid) herbicide resistance problems before they occur by looking at overseas problems that could, but have not yet developed in NZ; 2) Develop quick genetic tests, bioassays, and other tools, to detect resistance, understand the mechanisms involved, and model its spread and management; 3) Design farmer-centric, economically-sustainable and culturally acceptable interventions to manage herbicide resistant weeds (e.g. well-timed implementation of herbicidal control, crop rotation, cultivation, biological control, grazing); 4) Promote these methods via stakeholder engagement.

6.1.4 Weed population biology informs and disrupts weed management

Our research will: 1) Document the life history, and population dynamics of weeds; 2) Describe management-population interactions; 3) Model population processes under alternative management scenarios; 4) Translate research outputs to facilitate engagement with stakeholders to achieve the outcome.

6.1.5 Weed control economics informs and disrupts weed management

Our research will: 1) Document the economic costs and benefits of weed management; 2) Model the economics of alternative management scenarios; 3) Link weed population models with economics theory; 4) Translate research outputs to facilitate engagement with stakeholders to achieve the outcome.
6.1.6 Best practice pastoral weed management adopted by farmers

Our research will: 1) Evaluate the aspects of farmer behaviour and motivations that contribute to effective weed management interventions; 2) Test different outreach/engagement methods that facilitate the adoption of best practices, and participation in strategic regional approaches to management.

6.1.7 Effective riparian weed management

Our research will: 1) Evaluate the impacts and management of weeds at the waterway-farm boundary; 2) Determine the costs and benefits with respect to pest plants of the legally required riparian protection measures on farm systems; 3) Engage with stakeholders to improve farm outcomes related to weeds in riparian areas.

6.2. Alignment with internal and external strategies

This Strategy aligns directly with the AgResearch SCP through our shared responsibility, with other CRIs, for research supporting New Zealand’s biosecurity needs. There is also strong alignment with the AgResearch SCI 2012-2017 through Impacts 1 and 7 relating to improved productivity of pastures/forages. There is clear alignment with the AgResearch Science Plan 2016-2020, through Science Output 1(g) “Increasing our understanding of new and existing biosecurity threats [weeds, pests and diseases] to develop new or improved mitigation and management options and policy advice” under Strategic Priority ‘Enhance the performance of forages and animals’. Specifically, the Key Issues ‘Internal biosecurity’, ‘Herbicide resistance’ and ‘Alternatives to herbicides’ align directly with the AgResearch Science Plan’s intent to have, by 2020 “Effective and enduring management practices developed for existing and new pests that minimise pesticide use”. The strategy also aligns with the AgR strategy ‘Delivery of R&D to the Hill Country’ through its intent to provide “Pastoral pest and weed management” capability.

Externally, the strategy is aligned with the “Ministry for Primary Industries Science Strategy 2015” through its vision for “robust and relevant science to support and transform biosecurity” and to the Ministry of Business, Innovation and Employment’s National Statement of Science Investment 2015-2025 which recognises that NZ’s approaches to biosecurity are world leading and proposes to continue funding primary sector science. There is alignment with MBIE’s National Statement of Science Investment 2015-2025 regarding NZ’s approach to biosecurity being “recognised as world leading”, MFE’s Conservation and Environment Science Roadmap through its “biosecurity” theme and MPI’s Primary Sector Science Roadmap 2017 through its “Protecting and sustaining resources” theme.

6.3. Resourcing

In Table 3 we show, for each Outcome, the current and required future (> FY18) funding sources, collaborators, stakeholders and future human resourcing required > FY18 to fully realise the outcomes.
<table>
<thead>
<tr>
<th>Outcome</th>
<th>Funding source</th>
<th>$ (FY18)</th>
<th>Collaborators</th>
<th>Stakeholders</th>
<th>Capability &gt; FY18 FTE</th>
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**Abbreviations:** AAFC Agriculture and Agri-Food Canada; AERU Agribusiness and Economics Research Unit; Agrichem Agricultural Chemical Industry; Agcarm New Zealand Association For Animal Health And Crop Protection; B+L NZ Beef and Lamb New Zealand; CABI Centre for Agricultural and Biosciences International; CIB Centre for Invasion Biology; CSIRO Commonwealth Scientific and Industrial Research; Dairy NZ Dairy NZ; DIE Department of Invasion Ecology, Academy of Sciences Czech Republic; DoC Department of Conservation NZ; EBD Estación Biológica de Doñana; ERMANZ Environmental Risk Management Authority NZ; FAR Foundation for Arable Research; MWLR Manaaki Whenua - Landcare Research NZ; LU Lincoln University; MPI Ministry for Primary Industry; MU Massey University; NIWA National Institute of Water and Atmospheric Research; Penn State Pennsylvania State University; RCs Regional Councils; BS-UC Biological Sciences - University of Canterbury; Scion New Zealand Forest Research Institute Ltd; SSIF Strategic Science Investment Fund; SFF Sustainable Farming Fund; USDA US Department of Agriculture; UWA University of Western Australia, UU Uppsala University
7. Recommendations for positioning the AgResearch capability 2018 - 2028

**Improved internal biosecurity**

At AgResearch there are no dedicated research efforts in this area, although under the Better Border Biosecurity (B3) research area there are efforts to contain incipient invaders (e.g. velvet leaf). Also, previous research by AgResearch weeds scientists has provided several tools that can inform regional weed management decision-making. The focus of any new work in this space would be to facilitate efforts to keep areas free of weeds (at local and regional scales) that are problems elsewhere in New Zealand. Formalizing knowledge about this problem would be a useful first step. Currently there is no strategic approach to this, although farmers are interested in adopting better science-based practices to prevent the list of problem plants that they deal with from growing. Furthermore, Regional Councils require a robust, science-based decision support system to enable them to meet the requirements of the Biosecurity Act and its National Policy Direction for Pest Management when proposing weed species for their Regional Pest Management Plans. A key component of such a system has been developed and recently released by AgResearch [https://www.agresearch.co.nz/cba/cba.php](https://www.agresearch.co.nz/cba/cba.php). While tool development is essential, engagement efforts and training are also needed to improve adoption and utility.

**Increased suite of non-chemical control options**

AgResearch has an important program of research on thistle weeds in dairy and sheep farms. Biocontrol expertise (e.g. natural enemies, diseases, invertebrates, inundative methods, gene editing) needs to be increased to improve our capacity to develop novel non-chemical methods of control. In addition, the Foundation for Arable Research has supported research into cultivation practices that decrease weed and fertilizer input costs e.g. crop rotation, intercropping, no till methods. Such work needs to be continued. The interaction between the micro-biome, endophytic organisms, and weed abundance could be a fruitful line of investigation. Adoption of new cultural practices effectively requires us to influence stakeholders to change established practice (which is no small feat). Such efforts would ideally be carried out using multiple lines of influence (policy, law, outreach, and training).

The concept of ‘multi-targeting’ in biological weed control represents a unique opportunity for New Zealand to biologically control its most damaging group of pastoral weeds, the thistles. This group of about 64 species accounts for ¼ of all of our pasture weeds and is responsible for a large proportion of the country’s weed-induced lost pastoral productivity. The uniqueness of the opportunity, and the science stretch it will require, rests in the fact that New Zealand has no native thistles. Thistle subtribe-specificity would enable such agents to feed widely across our thistles controlling species that are well advanced along their invasion trajectories and also holding in check those in their lag phase, without risk to our native or economic flora.

**Herbicide resistance evolution understood and controlled**

AgResearch has used SSIF funds to establish expertise and has implemented successful projects studying the biological mechanisms and extent of herbicide resistance (e.g. modes of action) in some specific weeds/crops (e.g. perennial rye grass, buttercup). More work needs to be done to get ahead of this problem as little has been done on the 14+ weeds known to
exhibit one or more resistances. Furthermore, there are probably many unidentified problems, and others that are known to the agrichemical industry.

**Weed population biology informs and disrupts weed management**
AgResearch has used SSIF funds to continue to cultivate its expertise in this area. Such work allows management to target vulnerable life stages and identification of effective natural enemies. Population models would be greatly improved by understanding gene flow, and to identify populations that may exhibit different traits, and require different management. Future research needs to put greater emphasis in genetic analyses, including epigenetics as it relates to resistance evolution. In-house capacity in this area is needed.

**Weed control economics informs and disrupts weed management**
AgResearch has included analyses of the costs and benefits of weed management in several studies, but more needs to be done to answer questions about the economics surrounding weed spread, control, prevention, and eradication efforts. The interactions between population and economic models are important and experts who are able to work comfortably at the interface between these two areas are needed in-house (this may include ecosystem services approaches). Such work could lead to a more nuanced approach to weed management and produce impactful science leading to robust decision support systems for stakeholders. We envisage new best practices could be identified.

**Best practice pastoral weed management adopted by farmers**
AgResearch has an extensive record of work that examines effectiveness of the suite of tools (chemical and cultural methods) available for weed management in pastoral systems. Most work carried out at AgResearch addresses questions about agricultural best practice. Though no dedicated funds are spent on the adoption and uptake of best practices. It is clear that despite the knowledge being generated, best practices are not adopted. More needs to be done to understand why farmers adopt, or not, best practices. Added capacity is needed in the areas of social science (understanding farmer motivations) and in translating such understanding into action through engagement. Methods should be tested that facilitate adoption of best practices. This addresses the question of creating larger impacts on farm management across the country.

**Effective riparian weed management**
AgResearch is not working in this area at present. The current government has emphasized water quality management and raised concerns about farming impacts. There are also legal requirements for farmers to manage riparian areas to control run-off. The concern is that such areas could harbor weed populations that act as a source of weeds for adjacent farmers and increase on farm costs. Work should focus on understanding the extent of the problem and generating effective methods for establishing desirable riparian cover.

**Crosscutting themes**
More thought has to be put into translation of science into on-farm action and stakeholder engagement. This will require dedicated social science and outreach capability, as well as versatile science and technical staff with good communication skills that have the desire to work with stakeholders.

Overall, weed research in AgResearch would benefit from increased access to the best genetic/bioinformatic tools. Working effectively in this space will require that AgResearch invest in expertise, sequencing technology, and bioinformatic and computing (including programming) capacity. Ground breaking technologies like CRISPR, and similar are potentially available for disruptive science. As always, applied agricultural science relies heavily on robust statistics and economic analyses. Future work with an economic component would benefit from upfront involvement of dedicated economists.

Dedicated weeds technical staff with good botanical and general field skills are essential for increasing our science outputs, improving the statistical power and rigor of our studies, and for staying on top of the day to day business of running experiments.
8. Acknowledgements

The authors thank the following people for helping to identify and prioritise the pastoral sector weed management issues that have informed, this strategy: Rebecca Redmond, Tracy Nelson, Tony Connor, Robyn Dynes, Warren King, Katherine Tozer (AgResearch), Simon Fowler (Landcare Research), Kerry Harrington (Massey University), Phil Hulme, Seona Casonato (Lincoln University), Dave Hodges (Dairy NZ), Geoff Ridley (Beef+Lamb NZ), Laurence Smith (Environment Canterbury), Ivan Lawrie (Foundation for Arable Research), Janine Alfeld (Ministry for Primary Industries), Jan Quay (Agcarm), Chris Allen and Jim MacCartney (Federated Famers), George Kerse (Ravensdown), Han Eerens (Bayer NZ Ltd). We also thank Dr Alasdair Noble for helpful advice on the analysis, presentation and interpretation of the data from the workshop.

9. References


10. Appendix 1 - Weed management issues (morning session of the workshop)

Weed issues in the pastoral sector identified by the ten industry and twelve science representatives at the workshop on 20 November 2017 grouped into "Key Issues". The measure of the importance placed on each issue is given as the number of "Votes" allocated by the scientists and industry representatives at the workshop (each participant had three votes to allocate to each issue). The focus was on generic issues rather than particular weed species. The three issues in red were workshopped in detail in the afternoon session to identify short, medium and long-term Outcomes.

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<th>Key Issue</th>
<th>Issue identified by industry</th>
<th>Issue identified by scientists</th>
<th>Votes (industry)</th>
<th>Votes (scientist)</th>
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<td>Cropping, - Isolation - Largest biotic influence in yields - Our climate different, - Different biota? Mix - Diversity of crops - Rotation is essential - No GM, - Focus on “unique” features for NZ</td>
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<td>Behaviour change (needed)</td>
<td>Behaviour change - Short-term outcome: from reactive to proactive, - Medium term outcome: understand how to motivate people to change their biosecurity behaviour, - Long term outcome: farmers/community are being proactive and reducing the impacts of weeds</td>
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<td>To understand why farmers etc aren’t being proactive</td>
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<td>Decision processes driven by economics</td>
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<td>Thistles: - Validation of impact - concrete information - adding / variegated/California - Other information</td>
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Pastoral sectors is unique (cf rangelands)
- Must look after it
- How we look after it
- Limited international collaborators

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<td>Lack of herbicide options for diverse pasture mixtures</td>
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| Total                           | 129 | 100% |
Methodology

To develop an overview of pastoral sector weed management issues, a 1-day workshop was held at Lincoln on Monday 20 November 2017. The workshop participants were twelve scientists representing four New Zealand research organisations (AgResearch, Massey University, Lincoln University, Landcare Research) and ten representatives of New Zealand organisations with weed management responsibilities (Dairy NZ, Beef + Lamb NZ, Foundation for Arable Research, Regional Councils, Agcarm, Agrichemical companies (Ravensdown and Bayer), Federated Farmers, Ministry for Primary Industries).

The workshop was designed and facilitated by the AgResearch People & Culture team. It aimed primarily to identify and prioritise the weed management issues being faced by the pastoral sector. This was achieved in the morning session by the science and industry representatives listing, separately, the issues as they each saw them (one issue per ‘post-it’ note) then each identifying their top three issues (by adding a sticky dot to the relevant post-it note). These issues were later (after the workshop) grouped into eight higher level themes or Key Issues. The importance of each of these Key Issues was determined as the sum of the ‘votes’ (dots) received.

In an addition, the workshop considered, for a subset of issues, what success would look like in the short, medium and long-term and what science would be needed. This afternoon session (b), in contrast to the morning session, was qualitative. Due to time restrictions, it could address only three of the many issues identified in the morning session. These three issues were selected by GWB as representative of key overarching issues. Statements on what success would look like in the short- (1-5 years), medium- (5-10 years) and long-term (>10 years) for each of the three identified issues were asked for and recorded on A1 paper sheets. Due to the qualitative of this section of the workshop, a quantitative analysis and interpretation of the results was not possible.

In making our recommendations as to how the AgResearch weed research capability should be positioned over the next ten years, the Key Issues derived from the workshop, were considered for their alignment with the AgResearch Statement of Core Purpose, Statement of Corporate Intent 2012-2017 and the AgResearch Science Plan 2016-2020.

According to accepted theory, a good strategy is a high level plan for achieving one or more Goals in an environment of uncertainty and limited resources. It has three components, Diagnosis, Guiding Policy and Actions. The first two components concern strategy formulation and the third strategy implementation. The Diagnosis component defines/explains the nature of the challenge and the Guiding Policy component defines the Goal(s) of the strategy. The Actions component defines the steps that will be required to achieve the Goal(s).

Using this logic the Investment Committee’s points 1, 2 and 3 are elements of Diagnosis and point 4 concerns Guiding Policy and Goal development. Accordingly, the Actions (Implementation) component of this Weed Research Strategy is, strictly speaking, beyond the brief of this document and will be developed in detail through formal Project Planning processes during the lifetime of the Strategy; these are likely to draw on research ideas identified in the afternoon session of the workshop.
11. Appendix 2 – What would success look like? Notes from afternoon session of the workshop

Issue 2 “Inter-farm weed biosecurity”
**Environmental Needs**

**Current**  

1. **Pastoral weeds**: Not strictly a weed – no knowledge or plants known.
2. **Defining success**: Value of the impact.
3. **Funding**: Range $2 M/ha - $5 1045.
4. **Jointly science/industry collaboration**: On medium result.
   - i.e. release a biocontrol for thistle ‘group’.
   - Potential to be very broad.
5. Model the weed’s population dynamics in combination with the agent’s dynamics.
6. Bioherbicides (using plant pathogens)
7. Biocontrol of weed seed banks, root feeders, etc
8. Goats for weed control
9. Grazing management
10. Pasture plant breeding
11. What species are the most likely to work treated by biocontrol?
11. What species are the most likely to be successfully targeted by biocontrol?

12. What's new?
   - gene editing
   - 

Research collaborators:
- CABI
- CSIRO
- USDA
- 

Stakeholders:
- Beekeepers NZ
- 

Issue 7 (a) “Herbicide resistance management”
Defining success and key science

The workshop considered in detail the three sub issues ‘Inter-farm weed biosecurity’, ‘Herbicide resistance management’ and ‘Biological control of weeds’, components of the Key Issues ‘Internal biosecurity’, ‘Herbicide resistance’, and ‘Alternatives to herbicides’ respectively. Results as raw ‘data’ are in Appendix 2. Many ideas emerged for each sub issue regarding what success would look like and what science would be needed. We have not attempted to analyse or summarise these ideas since further discussion will be required on the other sub issues within each Key Issue to develop a clear picture of success and the appropriate science. Nevertheless, ideas recorded, along with other yet to be identified, will help inform project proposals during the life of the strategy.
12. Appendix 3 – Regional council perspective

Summary across regional councils (by Laurence Smith, ECan)

Where sectors want to be in 10+ years?

- Early detection improved – surveillance, spectral analysis – drones, aircraft, satellite
- Control tools enhanced – selective herbicides, non-chemical weed control is still a research need
- More effective management options
- Improved modelling to assess potential distribution
- Better educated public
- Responsibility for pests at a land occupier level.
- Technology advanced to enhance field data, reporting, trends, likelihood of new threats
- Science advising on best methods for managing risk vectors/pathways
- Improved hygiene by farmers and industry
- Solid relationship between all sectors resulting in collaborative initiatives e.g. On Farm Biosecurity and behaviour change, generic effort across NZ
- Better information and understanding of pest behaviours e.g. seed viability, germination, seed banks, movement factors etc.
- Resourcing of pest programmes, more collaborative funding e.g. RC’s, Industry, MPI etc.
- Recognition of the effects of climate and land use on pasture weeds
- TAG group/s to assess potential threats and resolve all aspects of incursion response at the regional level

What are the current, emerging and future weeds threats/ issues?

- Chinese Knotweed, Velvet leaf, Chilean needle grass, Nassella tussock, gorse, broom, yellow bristle grass, Russell and Yellow Lupin, Chilean Mayten,
- Issue – land use, land management and responsibility for pests on lifestyle/commercial/investment land
- Effects of climate change e.g. growing season is longer and plants that were unable to set seeds in the past in NZ (or part of) will potentially be able to do in the future.
- Pathway management - the most pressing issue facing the agricultural sector which needs national collaboration is the need for ‘On farm Biosecurity’. Currently it is being dealt with very locally and add hock with not a lot of collaboration within industry and RC’s.
- Funding regional weed programmes that have national implications (e.g. alligator weed, Chilean needle grass, horsetail) if there is a lack of resourcing by RC’s. The national burden falls on one or two regional council to manage and the implication of under resourcing is massive.
- Current lack of research into management tools where there is no wide scale commercial market for the research but the research is needed to deal with these high threat low incident pests.
• Identifying emerging pest threats and impacts.
• Effective economic impact assessments of threats, including Biodiversity costs of not intervening. Current/emerging threat = the invasion of CNG into dry, east coast pastoral systems and how to manage infestations effectively, while maintaining profitability, in this country.
• Surveillance and detecting new infestations (post boarder).
• Issue – the lack of responsibility by land occupiers, contractors and industry re spread prevention

Otago

1. In ten years time I think it will be the still old traditional weeds, broom, gorse, ragwort, nassella T and the range of thistle species will still be the most problematic in some pastoral areas of Otago. Other species which are a nuisance in cropping situations include the likes of fathen, storksbill etc.

   With pivot irrigation and biological control I believe the likes of nodding thistle is not the threat it once was in pastoral situations. Dairy farmers have been hot on controlling ragwort for years and rarely do we see it on a dairy farm now. Confined to life style blocks where they have sheep.

2. It’s reasonable to suggest in Otago we don’t have any real new threats that we know of that are emerging. Obviously we may well be in the firing line for CNG, and too early to predict if velvet leaf is going to be an issue for us. One concern with nodding thistle is that its distribution is still increasing across the region but generally the density at sites is usually quite low compared with what it used to be like.

Auckland

1. Where sectors want/need to be in terms of pastoral weed management in 10 + years’ time?

   Education within the sector and ongoing technical support will be a big area in future especially with many new immigrants that have little understanding of rural management and the threat posed by pastoral weeds. Biosecurity hygiene in particular is an area we are lacking and the importance of managing vector pathways with science based practical application.

2. What are the current, emerging and future weeds threats/issues from your perspective?

   Land bankers are becoming common around rural Auckland as well as lifestyle blocks where owners no little about effective land management is becoming a huge issue as these are becoming a real source of pest plants to the commercial rural community.
Emerging pest plants are coming over the border include Chinese Knotweed as well as Velvet leaf are ongoing.

With climate change many pastoral weeds that have been restricted to warmer regions are now able to establish in other regions, their growing season is longer and plants that were unable to set seeds in the past in NZ will potentially be able to do in the future.

Hawkes Bay

Regarding where sectors want/need to be in terms of pastoral weed management in 10 + years' time? We need to find a better way to find these weeds regarding surveillance so spectral analysis via drones/planes/satellites would be helpful. Understanding the weeds we target in regards to seedlife, when seeds mature etc is useful as well.

Big threat in Hawke’s Bay is Calamint and CNG.

Waikato

1. Where sectors want/need to be in terms of pastoral weed management in 10 + years' time?
   a. Based on our experience with Velvetleaf and Yellow Bristle Grass –
      i. Key groups - NZ Agricultural Contractors association, Seed/sales merchants (Pioneer, Farmlands, PGG Wrightsons), Dairy NZ, Beef & Lamb, AgReserach, FAR. Chemical Reps, politicians.
      ii. Secondary groups – Federated Farmers, Agricultural consultants, Roading Authorities, media.

2. What are the current, emerging and future weeds threats/issues from your perspective?
   a. Pathway management - I think the most pressing issue facing the agricultural sector which needs national collaboration is the need for ‘On farm Biosecurity’. Currently it is being dealt with very locally and add hock with not a lot of collaboration.

   b. Funding regional weed programmes that have national implications (e.g. alligator weed, Chilean needle grass, horsetail) if there is a lack of resourcing by RC’s. The national burden falls on one or two regional council to manage and the implication of under resourcing is massive.

   c. Weed led - In the Waikato, Alligator weed is the most pressing issue for us and the rest of the North Island for the reasons listed above.

   d. Tools/technology –
i. There is a lack of the research into management tools (e.g. herbicides) where there is no wide scale commercial market for the research but the research is needed to deal with these high threat low incident pests.

ii. There needs to more support for trialling and undertake eradication of pests rather than going straight to containment.

iii. Effective economic impact assessments of threats.

e. Surveillance and detecting new infestations (post boarder).

f. Basic strategic planning for pest management that is inter-regional and resourced.

Marlborough

1. Where sectors want/need to be in terms of pastoral weed management in 10 + years’ time?

   As with Craig, early detection techniques to tip the chance of preventing establishment of a new invasion back in the manger’s favour

2. What are the current, emerging and future weeds threats/issues from your perspective? Current/emerging threat = the invasion of CNG into dry, east coast pastoral systems and how to manage infestations effectively, while maintaining profitability, in this country.

   Future issue = modelling spread potential under a warming climate and down to a finer scale on the landscape.

Horizons

1. Detection of pasture weeds – I heard about yesterday in passing from Paul Peterson from Landcare Research where Massey have hyperspectral capability to detect different grass types in a field.
2. Selective control of grass weeds – Chinese, nasella, etc
3. Spread prevention – social factors and tools to trigger and effectively decontaminate. Elbow grease is so last century it seems.