1  **The economic impact of failures in plant protection to New Zealand**

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14  **Abstract**
15

16 Plant weeds, pests and diseases comprise significant threats to pastoral agriculture in New
17 Zealand. The extent of damage incurred by New Zealand's agricultural industry from these
18 weed and pest threats varies significantly depending on the response implemented, and the
19 technologies available. This paper assesses the projected economic impact of three individual
20 potential failures in plant protection, specifically the spread of clover root weevil, giant
21 buttercup and glassy-winged sharpshooter across New Zealand, and the potential mitigation
22 of economic loss caused by these failures through various response methods. This assessment
23 is carried out with the use of a national-level agricultural production and value model, based
24 on data from the Ministry for Primary Industries farm models and the Lincoln Trade and
25 Environment Model, an international trade and environment model. The model projects
26 economic impact on agriculture until 2030, comparing the differences in economic impact
27 between business as usual without the advent of each threat and then with the advent of each
28 threat alongside various potential responses. The modelled responses cover firstly the most
29 probable responses, and secondly the use of biological control agents, in the form of a
30 parasitoid or bio-herbicide control. The results show that biological controls offer the most
31 effective and feasible responses to the modelled threats to pastoral agriculture compared with
32 other responses.

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## Introduction

New Zealand is particularly vulnerable to the impact of weeds, pests and diseases (Goldson et al., 1997) and, significantly, it has been estimated that over 90% of this country's invertebrate pests are alien invasive species (Barlow and Goldson, 2002). Despite this, the severity of pest impacts is often overlooked as a source of economic loss and environmental degradation because the impacts of pest damage are frequently being attributed to other causes such as poor seed strike. This misattribution can occur for a variety of reasons, including the often cryptic or camouflaged appearance of pest species, concealed feeding sites (e.g. root-feeding or stem-mining habits) and ambiguous damage symptoms. The latter particularly applies to pathogens which can produce very non-specific symptoms. Unsurprisingly, therefore, and in an attempt to correct such misapprehension over recent years, quite a number of contributions have been made by bioprotection researchers themselves to produce monetary estimates of damage. In particular, this has pertained to analyses into pasture/forage pests (Prestidge Barker & Pottinger,1991; Goldson, Proffitt & Muscroft-Taylor, 1993; Barlow and Goldson, 2002; Goldson, Rowarth & Caradus, 2005) and weeds (Bourdôt et al., 2012; 2013). However, this has also generally applied to the land-based industries (Suckling and Popay, 1993). Particularly spectacular estimates have been made of the financial impacts of pasture damage. This is simply because 50% of the land area of New Zealand is pasture and the multipliers are therefore very high. As a result, such estimates have been met with scepticism often because they have been generated without the imprimatur of well recognised economists and therefore have apparently not always been accepted. A notable exception to this was the work of Bertram (1999). Partly in response to such circumstances this contribution seeks to confirm via standard econometric methods earlier economic estimates of impacts based on a pasture pest, a pasture weed and an estimate of the likely impact of a potential pest species of grapes.

Primary industries are of high importance to New Zealand, in particular the agricultural sector, contributing $9.4 billion to GDP, or 6.4% of total GDP in 2012 (Statistics NZ 2013). One of the most significant threats to New Zealand's agriculture is the occurrence of failures in plant protection; these can be pests, weeds or plant diseases becoming more important or developing from new invasions. One recent example of a failure in plant protection is the PSA outbreak on kiwifruit, which has been estimated to cost between $310 and $410 million to New Zealand agriculture, over 5 years (Greer & Saunders, 2012).

This project demonstrates the economic cost to agriculture in New Zealand of the spread of various biological pests, weeds and diseases. To estimate this, a model has been developed to map these economic impacts and the economic value of different mitigation and biocontrol responses to challenges, thus showing value of having strong bioprotection science to anticipate, meet and mitigate these challenges and threats.

This paper focuses solely on the effects of challenges to New Zealand's pastoral industries, other impacts on New Zealand's biodiversity profile, or potential and flow-on effects to other industries have not been accounted for.

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## Methodology

80    Three scenarios of damaging pests and weeds in New Zealand agriculture were modelled;
81    these represent a range of current and potential challenges to agriculture in New Zealand. The
82    selected scenarios are detailed in Table 1.

83

84                                      **Table 1: Scenario descriptions**

| Scenario | | Responses | |
|---|---|---|---|
| # | Name | First | Second |
| 1 | Clover root weevil | Increased N use | Parasitoid biological control |
| 2 | Giant buttercup | Increased herbicide | Bio-herbicide |
| 3 | Glassy-winged sharpshooter | Replanting vines | Bio-herbicide |

85

86    Each scenario models the outcome from a lack of plant protection for a particular farm type
87    in New Zealand, and presents up to three different approaches for mitigating the negative
88    effects on production. As presented, the mitigation approaches are informed by the literature
89    surrounding each case and personal communication with scientists in the relevant fields, thus
90    describing the most useful responses available or potentially available within the modelling
91    timeframe. The mitigation responses cover approaches such as the use of biological controls
92    for pests or weeds, changes in farm systems and farm inputs and/or the use of specific
93    pesticides or herbicides. In each of these cases the cost of implementation and the beneficial
94    effect of the implementation are accounted for.

95    Quantifying the incidences and spread of a pest or weed, and the probable mitigation
96    responses was achieved by taking the data and projections from the literature and personal
97    communication with plant protection specialists where available. Some scenarios, however,
98    also encompass potential responses to these challenges that are outside New Zealand's
99    experience, for example a scenario deals with an incursion of a pest until now unknown to
100   New Zealand agriculture, or mitigation technologies that are still in the preliminary stages of
101   development or have yet to be released for wide-scale application. In these cases, estimates
102   were derived from case-studies of foreign incursions and with the guidance of specialists.

103   **Model**

104   An economic impact assessment model was developed to quantify the effects of these
105   challenges to plant protection. The model uses both data from the Lincoln Trade and
106   Environment Model (LTEM) and the Ministry for Primary Industries (MPI) farm monitoring
107   reports. The LTEM component gives national level projections derived from trading
108   conditions for production and price figures for agricultural commodities up to 2020. These
109   projections are then disaggregated to the farm level and normalised to the budgets for MPI's
110   model farms as of the 2011 farm monitoring reports (Ministry of Agriculture and Forestry:

111  MAF, 2011a; MAF, 2011b; MAF 2011c; MAF 2011d). The approach allows for both the
112  projections and international trade effects of the LTEM's national focus to be applied to farm
113  level profits, taken from MPI. The model currently projects to 2030, using linear
114  extrapolations of the projection given by the LTEM.

115  The effects of pests and weeds, and the recovery scenarios can be modelled as changes to
116  either total production, price, total or per hectare income, total or per hectare cost or stocking
117  rates. These changes can be applied to any year within the model's operating timeframe, or
118  gradually over a designated time period.

119  The model gives outputs in profitability by commodity and scenario at an aggregate national
120  level, using a discount rate of 8%. Also presented are the losses for each scenario compared
121  to the baseline, and the benefits of the recovery scenarios compared to the initial loss
122  scenario. These results are given for both the entire period of modelling and per hectare per
123  year.

**Scenario 1**
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**Clover Root Weevil**
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127  The clover root weevil (*Sitona lepidus*) is a pasture pest native to Europe which was
128  discovered in New Zealand in 1996 (Gerard et al., 2007a), and by 2005 was present in
129  pastures across the North Island (Gerard et al., 2009). Currently the weevil is spreading
130  through the South Island.

131  All stages of the weevil affect white clover and this has two impacts on pastures. First is the
132  loss of dry matter through the depletion of clover due to feeding. Second is the loss in
133  nitrogen fixation also due to rhizobial root nodule damage.

134  In most assessments of the effects of this weevil, estimates of the loss to pasture have been
135  based on records of damage found on Waikato dairy farms. In such farms, the weevil causes
136  up to 35% reductions in total dry matter and up to 83% less nitrogen fixed as a result of
137  clover loss (Gerard, Hackell & Bell, 2007a). These effects would be less severe nationally
138  due to lower clover content of pastures in other regions. Because of this, a 10% reduction in
139  the production of milk solids, beef and sheep, has been used for this report. This is the same
140  approach that was used in the medium impact scenario from the New Zealand Institute of
141  Economic Research (NZIER)'s earlier assessment of the impacts of the clover root weevil
142  (Wear & Andrews, 2005).

143  The weevil is thought to spread at a rate of 35 km/year on average (Willoughby & Addison,
144  1997). Applying this to the map of current weevil distribution throughout the South Island
145  developed by AgResearch (Figure 1) we can assume that all of New Zealand pasture will be
146  affected by the weevil by 2014 and equilibrium populations of the weevil will be fully
147  established by 2015.

148

149 **Figure 1: Current South Island distribution of CRW & its biological control agent.**
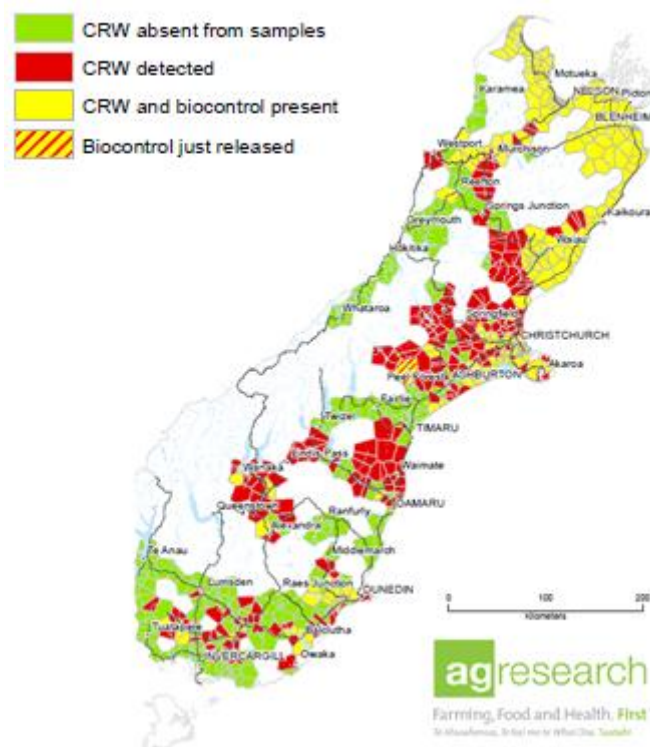


150
151                              Source: Phillips et al., 2013.

152 **Response scenarios**

153 For the impact of the clover root weevil on New Zealand agriculture, two mitigation
154 responses are modelled. The first is an increase in the use of nitrogen fertiliser the second is
155 spread of a weevil parasitoid as a biological control agent.

156 *Response 1: Increased use of nitrogen*

157 One current response to the damage incurred by the spread of the weevil is the use extra
158 nitrogen fertiliser to offset the reduced nitrogen fixation resulting from clover damage, and
159 the loss in consumable dry matter on pasture. The assumptions and data informing this
160 mitigation scenario were taken from the NZIER's report on the economic impact of clover
161 root weevil (Wear & Andrews, 2005) and the 2010 Lincoln Financial Budget Manual
162 (Pangborn, 2010). It is assumed that clover naturally releases 200 kg nitrogen/year/hectare,
163 and that clover root weevil prevents nitrogen fixation in 50% of the nodules. Therefore, 100
164 kg of nitrogen must be replaced via fertiliser to maintain pasture production at normal levels.
165 The costs associated with such extra application of nitrogen fertiliser are detailed in Table 2.

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169 **Table 2: Cost for replacing nitrogen (N) lost due to clover root weevil nodule damage**

| | |
|---|---|
| N deficiency | 100 Kg/ha/yr |
| Urea (46% N) required | 217.39 Kg/ha/yr |
| Price of Urea (FBM) | $620/t |
| Application Cost @ $48.20/ha (FBM) | $10.48/ha |
| Cartage Cost for 30km @ $16/t (FBM) | $3.48/ha |
| Total Cost | $148.74/ha |

170 FBM: Farm Budget Manual (Pangborn 2010)

171

172

173 The use of extra nitrogen to mitigate the effects of clover root weevil has been shown to
174 increase total pasture production, but cause a slight decrease in total metabolisable energy
175 (White & Gerard, 2006). This was found to be due to a reduction in clover content of the
176 pasture from weevil activity, but an increase in total ryegrass due to the application of
177 nitrogen. For the purposes of modelling we have assumed this to equate to pre-weevil
178 production levels, occurring as a lagged response, one year after the full establishment of the
179 weevil.

180 This response is sensitive to the cost of nitrogen fertiliser and the capability of land to bear
181 additional nutrient load. This scenario does not take into account the negative groundwater
182 effects, which using extra nitrogen fertiliser on a national level would incur. Tait and Cullen
183 (2006) estimate the external costs of dairy farming in Canterbury to surface and groundwater,
184 air, biodiversity and human health at $28.7 to $45 million per annum. Of this amount,
185 $155,000 per annum is the specific impact on surface and groundwater, which would be
186 affected by increased nitrogen use on farm. Greenhouse gas emissions per hectare would also
187 increase with additional fertiliser use. Calculating the impacts from the increase of nitrogen
188 fertiliser applied in this scenario would require additional resources beyond the scope of this
189 project.

190 Furthermore, current discussion around the environmental impacts of agricultural use of
191 nitrogen, suggest that limits to the use of nitrogen on farm may be implemented in the near
192 future by regional councils. Such limits would make this scenario an unfeasible option for
193 response to the incursion of the clover root weevil.

194

195  *Response 2 & 3: Biological control*

196  The second modelled response to the impacts of clover root weevil is based on the use of a
197  biological control agent, the wasp *Microctonus aethiopoides* (Irish strain)*,* which is a
198  parasitoid of the weevil (Goldson, Rowarth & Caradus, 2005; McNeill et al., 2006). The
199  wasp usually lays one egg into each adult weevil, rendering the female infertile and killing it
200  upon the emergence of the fifth instar larva. The wasp was released in 2006 and has since
201  been established in most New Zealand regions, spreading at about 15km a year which is
202  20km/year slower than its host.

203  For the modelling exercise the biological control is presumed to have been introduced at the
204  start of the modelling timeframe, and established nationwide in 2018, 3 years later than the
205  weevil. Once established and accommodating any associated density-dependent processes,
206  the Irish wasp is assumed to lead to yields of up to 80% of the original potential production.
207  As the level of control given by the Irish wasp varies, two scenarios have been modelled: the
208  first, a lower estimate of 60% of original yields, the second an upper estimate of 80% of the
209  original pasture yield.

210  This biological control is modelled as having no additional cost to farmers.

211  **Results**

212  Figure 2 illustrates the outputs of the model for the clover root weevil impact scenarios. The
213  base scenario shows the business-as-usual projections from the LTEM for New Zealand's
214  pastoral sector without any impact from clover root weevil. The initial scenario shows these
215  projections with the damage caused by the incursion and eventual establishment of the clover
216  root weevil in New Zealand pastures. Three recovery scenarios are shown in Figure 2:
217  additional N use (+ N use) shows the effect of extra nitrogen fertiliser to compensate for the
218  decrease in clover N fixation and total dry matter, and biological control 60% and 80% show
219  the establishment of the parasitoid biological control giving yields at 60% and 80% of clover
220  root weevil, respectively.

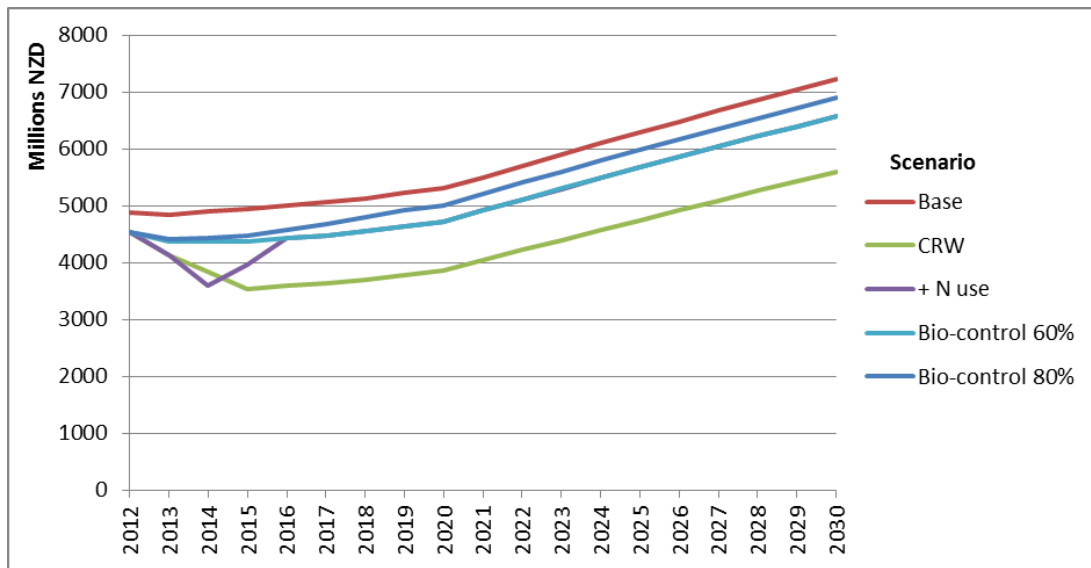221  **Figure 2: Clover root weevil's impact on New Zealand pastoral profits until 2030**

222

223 Table 3 shows the total loss from the incursion of clover root weevil within the timeframe of
224 the modelling exercise at over $11 billion. Nitrogen replacement or the first recovery scenario
225 would mitigate over $5 billion worth of losses, whilst the full establishment of the parasitoid
226 biological control at by 2018 would mitigate over $6 billion NZD at 60% parasitism. At the
227 80% figure this amounts to the parasitoid biological control being worth $400-$500 million
228 per year.

229 **Table 3: Total change in pastoral profits 2012-2030, for a range of clover root weevil**
230 **scenarios**

| | Total (milNZD) | Mitigation (milNZD) |
|---|---|---|
| **Clover root weevil** | -11,467 | - |
| **Additional N use** | -6,156 | 5,311 |
| **Biological control 60%** | -5,054 | 6,413 |
| **Biological control 80%** | -3,278 | 8,189 |

231

232 Figure 3 shows the total losses incurred by clover root weevil against the mitigation resulting
233 from the three response scenarios. The 80% biological control has the greatest mitigation,
234 whereas the additional use of nitrogen and the 60% biological control give roughly the same
235 mitigation rate by 2030.

236

237 **Figure 3: Total loss and mitigation in pastoral profits 2012-2030, for clover root weevil**
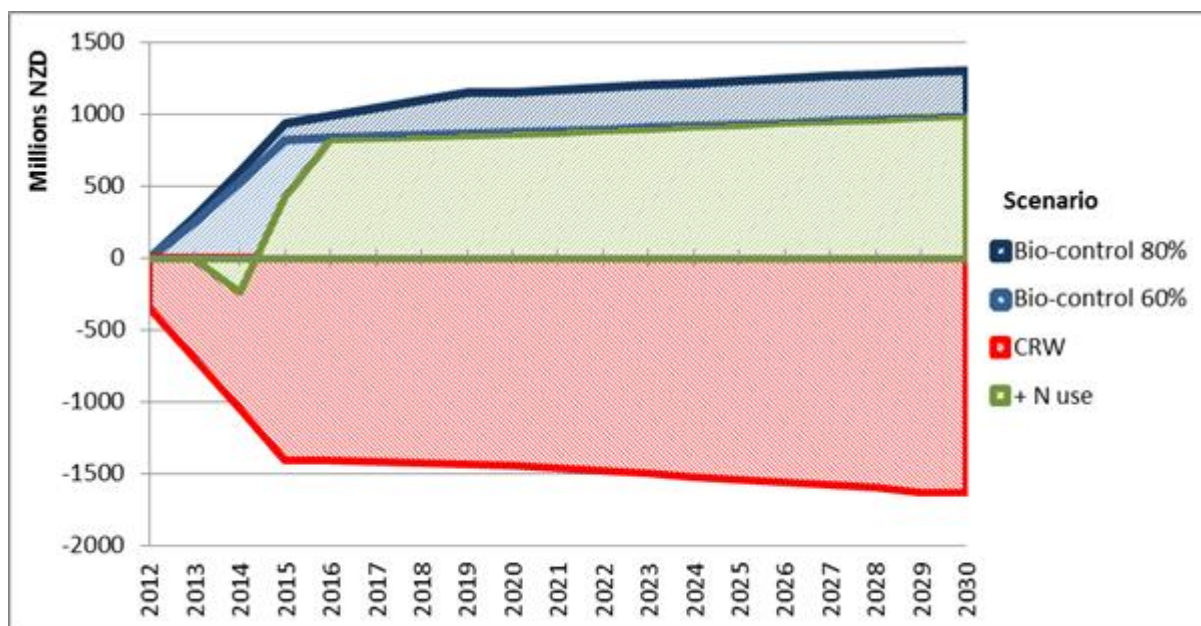238 **scenarios**

**Table 4: Total change in pastoral profits annuitized, for clover root weevil scenarios**

|  | Total (milNZD) | Mitigation (milNZD) |
|---|---|---|
| **Clover root weevil** | -604 | - |
| **Additional N use** | -324 | 280 |
| **Biological control 60%** | -266 | 338 |
| **Biological control 80%** | -173 | 431 |

In order to further break down and illustrate these results Table 4 presents the profits for each scenario annually, and Table 5 shows the annuitized profits by hectare. Clover root weevil is then expected to reduce pastoral profits on average by $81 per hectare, where additional N could mitigate about half of this, and the biological control between 55% and 72%.

**Table 5: Total change in pastoral profits annuitized per ha, for clover root weevil scenarios**

|  | Total (NZD) | Mitigation (NZD) |
|---|---|---|
| **Clover root weevil** | -81.36 | - |
| **Additional N use** | -43.68 | 37.68 |

| | | |
|---|---|---|
| **Biological control 60%** | -35.86 | 45.50 |
| **Biological control 80%** | -23.26 | 58.10 |

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251

252 **Scenario 2**

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254 **Giant Buttercup**

255 Giant buttercup (*Ranunculus acris*) is a weed currently present in pastures in six of the 16
256 dairying regions of New Zealand. The weed is unpalatable to ruminants and thus causes a
257 drop in the metabolisable content of pasture land as cattle avoid the weed and pasture
258 surrounding it. In this way the giant buttercup is thought to cost the New Zealand dairy
259 industry $156 million per year (Bourdôt & Saville, 2010). The weed is expected to eventually
260 spread throughout New Zealand pasturelands, albeit slowly. The following scenarios assume
261 the weed will have spread across New Zealand by 2027.

262 Giant buttercup also occurs on sheep and beef land; however, here it does not become a
263 problem weed "usually persisting as stunted plants that fail to reach above the pasture
264 canopy" (Bourdôt & Lamoureaux, 2002). Thus, giant buttercup is modelled as only affecting
265 dairy pastures.

266 A study on the economic impacts of giant buttercup (Bourdôt 2003) uses 33.24% as an
267 estimate of loss of usable dry matter. The loss in production from giant buttercup nationwide
268 is based on this estimate in the modelled scenarios.

269 *Response 1: Extra herbicide use*

270 The first modelled response to the spread of giant buttercup is based on the use of a
271 flumetsulam herbicide. This herbicide is currently one of the most effective agents for
272 controlling giant buttercup. Prior to this the phenoxy herbicide 2-methyl-4-
273 chlorophenoxyacetic acid (MCPA) had been used to control the weed; however, this
274 chemical has been losing its effectiveness, thereby requiring continously increasing rates of
275 application as resistance has increased. Bourdôt & Lamoureaux (2002) noted that MCPA
276 treatment would need to be withheld from a resistant population for 28 years prior to a return
277 of level of buttercup susceptibility that would give effective control.

278 Harris & Husband (1997) showed that annual repeat application of flumetsulam at label rates
279 of 50g/ha over consecutive years provided 80% control of giant buttercups after 4 years.
280 These figures have been adopted in the model used in this contribution, along with per
281 hectare application costs as detailed in Table 6, using current label rates for giant buttercup
282 control of 65g/ha with a flumetsulam herbicide. This is an underestimate of cost as, over

283 time, resistance is likely to occur requiring application rates of the herbicide exceeding label
284 rates, thus increasing total cost.

285

286 **Table 6: Per hectare (ha) cost of applying flumetsulam**

| | |
|---|---|
| Flumetsulam (Preside) required | 65g/ha |
| Spraying Oil (Uptake) required | 1L/ha |
| Cost of Flumetsulam (Preside) & Spraying Oil | $44.85/ha |
| Average ground application cost | $26/ha |
| Total Cost | $70.85/ha |

287

288 *Response 2: Biological control*

289 One potential alternative response to the spread of giant buttercup is the application of a
290 naturally-occuring fungus, *Sclerotinia sclerotiorum*, which can infect and kill buttercups.

291 The fungus has been found to cause 75% plant mortality rates in controlled studies, and 50%
292 and 57% plant mortality in dairy pastures (Cornwallis et al., 1999; Green et al., 1993 Harvey
293 & Bourdôt, 2001). Pasture plants are thought to be more resistant to infection, being older
294 and larger than their counterparts in controlled environments. Currently, methods are being
295 explored to increase the mortality rate in pastures. For this modelling exercise, a 50%
296 mortality rate of the giant buttercup from the application of *S. sclerotiorum* has been adopted.
297 Under this assumption it can be estimated that if the fungal biological control agent is applied
298 in the field for six years, the giant buttercup would thereafter have a minimal effect on
299 production.

300

301 For modelling purposes it is assumed that the *S. sclerotiorum*-based bio-pesticide has been
302 developed to the extent that it is useful for commercial application (estimated requirement
303 time is 3 years). The estimated cost of this biological control has been placed at $300 per
304 hectare (G. Bourdôt pers. comm, 2013). The costs of applying the biocontrol *S. sclerotiorum*
305 are estimated to be $26 per hectare, the same as the ground application of flumetsulam. Due
306 to the high modelled cost of this biological control option, it is only considered applicable to
307 use on dairy land as the profit margins for sheep and beef farming are not sufficient for this
308 product to be economic at $326 per hectare.

309

310  **Results**
311

312  Figures 4 & 5, and Table 7 show that the spread of giant buttercup could cost New Zealand
313  upwards of $18.8 billion over 18 years. The use of extra herbicides on affected pastures
314  would mitigate almost 60% of these losses, and the use of the fungus *Sclerotinia sclerotiorum*
315  as a bio-herbicide would mitigate almost 70%.

316

317  **Figure 4: The impact of giant buttercup on New Zealand dairy profits until 2030**

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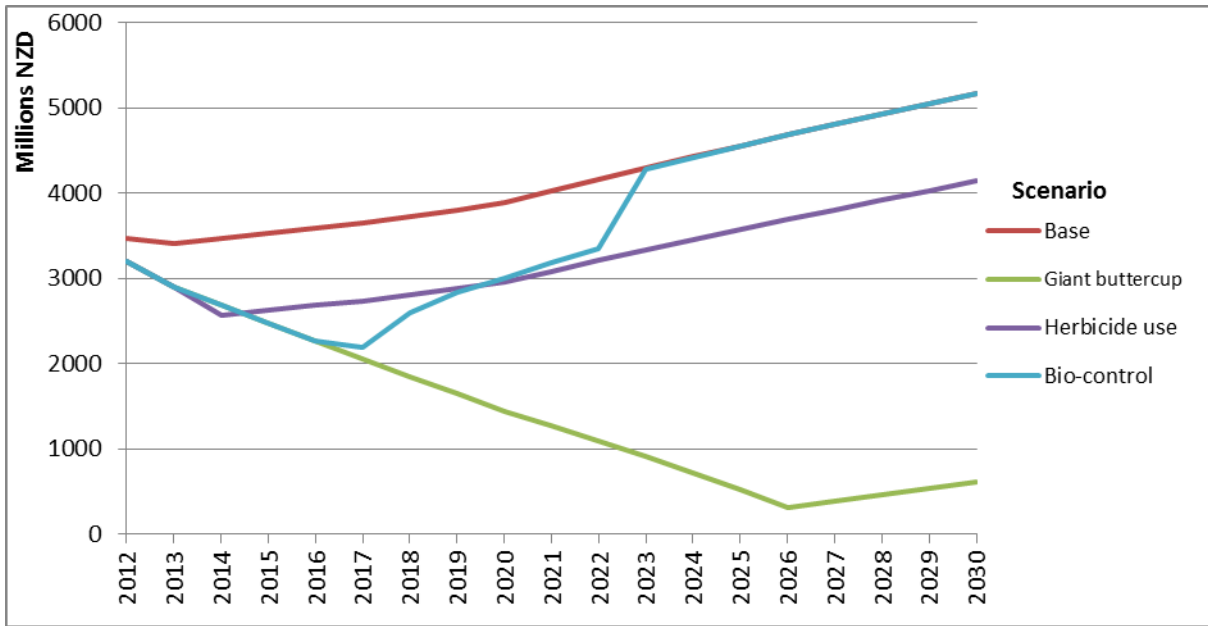


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321  **Table 7: Total change in dairy profits 2012-2030, for the Giant buttercup scenarios**

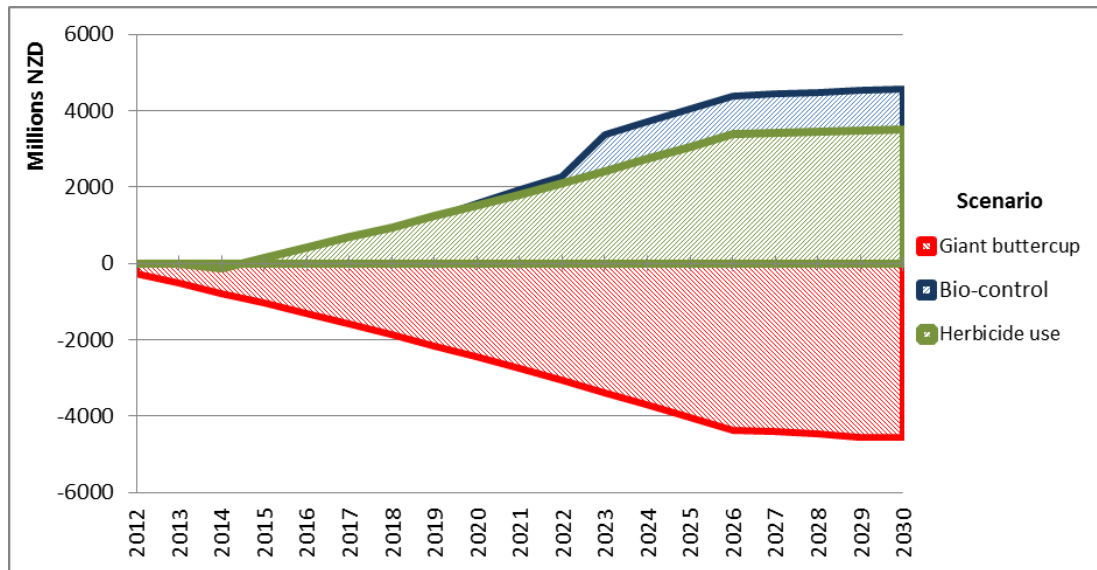| | Total (milNZD) | Mitigation (milNZD) |
|---|---|---|
| **Giant buttercup** | -18,810 | - |
| **Herbicide use** | -7,621 | 11,189 |
| **Biological control** | -6,042 | 12,767 |

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327 **Figure 5: Total loss and mitigation in dairy profits 2012-2030, for the giant buttercup**
328 **scenarios**



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332 Table 8 shows the total changes in each scenario averaged across the effected period. Giant
333 buttercup causes a loss to dairy of almost a billion dollars a year.

334

335 **Table 8: Total change in dairy profits annuitized, for the giant buttercup scenarios**

| | Total (milNZD) | Mitigation (milNZD) |
|---|---|---|
| **Giant buttercup** | -990 | - |
| **Herbicide use** | -401 | 589 |
| **Biological control** | -318 | 672 |

336

337 Per hectare, shown in Table 9, the spread of giant buttercup would cost over $640, this would
338 be reduced to approximately $245 with the use of flumetsulam, finally with the bio-herbicide,
339 it would cost $194, mitigating $410 per hectare.

340 **Table 9: Total change in dairy profits annuitized per hectare (ha), for the giant**
341 **buttercup scenarios**

| | Total (NZD) | Mitigation (NZD) |
|---|---|---|
| **Giant buttercup** | -604.18 | - |
| **Herbicide use** | -244.80 | 359.39 |
| **Biological control** | -194.08 | 410.10 |

342

**Scenario 3**

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344

**Glassy-winged sharpshooter**

345

346 The glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis*, is a leafhopper insect
347 native to Mexico, which can cause widespread damage to citrus trees, grape vines and arable
348 crops through feeding and the spread of Pierce's disease (PD).

349 PD affects grape vines by blocking the plant's xylem leading to vine death within one to five
350 years. PD is caused by a strain of the bacterium *Xylella fastidos,* and there is no known cure
351 for the disease or the direct prevention of it.

352 While the GWSS causes damage to citrus trees through water loss associated with feeding, its
353 main potential threat to the New Zealand agricultural industry is in its capibility to spread the
354 bacterium that causes PD. This disease already exists in New Zealand, but there are currently
355 no New Zealand vectors of the disease capable of tranferring the disease to grape vines.

356 When the GWSS feeds on an infected plant, the disease-causing bacteria can attach to the
357 sharpshooter's mouth and colonise its gut, thereby providing a reservoir for the bacteria to be
358 transferred to other plants.

359 The GWSS spread to California in the late 1980s and from there has spread to French
360 Polynesia in 1999, Hawaii in 2004 and the Cook Islands in 2007, showing the sharpshooter's
361 ability to be spread through air travel, and move closer to New Zealand.

362 In California, the incursion of GWSS and the spread of PD is estimated to cost the
363 Californian wine industry 110 million USD each year (Alston et al., 2012), $59 million of
364 this is from the loss of productivity in grape growth, the remaining $51 million is spent on
365 preventative measures and funding the Pierce's Disease Control Program.

366 The modelled scenario of the spread of GWSS to New Zealand focuses only on the impact on
367 grape growers, although there is evidence that an incursion would also impact on citrus
368 growers, and native trees and shrubs.

369 The whole of New Zealand is thought to be climatically suitable for GWSS; however, PD is
370 only severe in the United States where the average minimum January temperature is greater
371 than 4.5°C, thus it is only a threat to North Island grape growers.

372 It is assumed that the spread of GWSS in New Zealand would be similar to its spread over
373 California. Maps showing the prevalence of the GWSS in California from the Californian
374 Department of Food and Agriculture show that it has spread approximatelly 600 miles over
375 seven years, from this GWSS was modelled to be fully established across the North Island
376 eight years after its first incursion. Following the establishment of the GWSS, grape yield's
377 are modelled as declining to zero over four years due to vine death associated with PD.

378

379 *Response 1: Replanting vines*

380 The first response scenario for the incursion of GWSS and PD is to uproot the vines and
381 replant. This option is extremely costly, incurring both the cost of replanting all affected
382 vines, but also the loss of revenue from a cessation of production as the new vines mature.

383 In modelling, the new vines are assumed to take four years to mature. The capital costs of
384 replanting per hectare, shown in Table 10, are spread over 30 years.

385 **Table 10:Replanting cost/hectare**

| | |
|---|---|
| Cost of plant material | $16,566 |
| Cost of vine guards | $3,012 |
| Pulling old vines | $8,031 |
| Planting vines | $5,722 |
| Replanting | $331 |
| Training for 3 years | $1,807 |
| Total | $35,469 |
| Lost grape income for 3 years | $45,000 |
| Total | $80,469 |
| Lost wine income for 3 years | $195,840 |
| Total | $276,309 |

386 Source: G. Creasy, pers. comm., 10 Sep 2013

387 The replanting of affected vines restores productivity; however, it does not grant any
388 increased resistance against future incursions of GWSS. Future infections of the new vines
389 are possible. This modelled response only simulates single replants with no second incursions
390 within the shown period.

391

392 *Response 2: Biological control*

393 The second response scenario for the GWSS scenario is the establishment of a parasitoid of
394 GWSS. Many species of parasitic wasps have been considered and used for the control of the
395 GWSS in California. For this model, we focus on *Gonatocerus ashmeadi*, which has been
396 used effectively in controlling the GWSS in Tahiti. *G. ashmeadi* is thought to have no
397 negative effects on other New Zealand insect fauna (Biosecurity New Zealand), and thus
398 could be introduced promptly following an outbreak of GWSS.

399 *G. ashmeadi* has reduced populations of GWSS in Tahiti by over 90% one year after release,
400 and up to 95% on eight islands across French Polynesia (Grandgirard et al., 2008).

401 It has been argued that the colder climate of New Zealand will be less suitable for the
402 establishment of *G. ashmeadi* (Charles & Logan, 2013), suggesting that the parasitoid may be
403 less effective across the whole of New Zealand than it has been in California and the Pacific.
404 In the warmer regions of the North Island the wasp should still be effective, although slower
405 to respond to increases in populations of GWSS. As the model's aim is only at assessing the
406 impacts of the spread of PD on North Island vineyards, which are predominantly located in

the warmer regions, we have assumed the wasp to be effective in areas with the GWSS.
Given the success of *G. ashmeadi* in French Polynesia (Grandgirard et al., 2008) a
conservative estimate of a 85% reduction in the populations of GWSS has been made. It is
also presumed that the GWSS would take eight years to become established across the North
Island.

There have been no extra costs assumed for the establishment of *G. ashmeadi*, although it is
recognised that this would incur costs via the New Zealand Environmental Protection
Authority.

**Results**

The majority of New Zealand's viticulture profits come from vineyards in the South Island,
thus whilst the GWSS is expected to cause great losses in North Island vineyards, it would
have a relatively small effect on New Zealand's grape industry as a whole, as shown in
Figure 6.

**Figure 6: The impact of the glassy-winged sharpshooter on New Zealand's viticulture
profits until 2030**
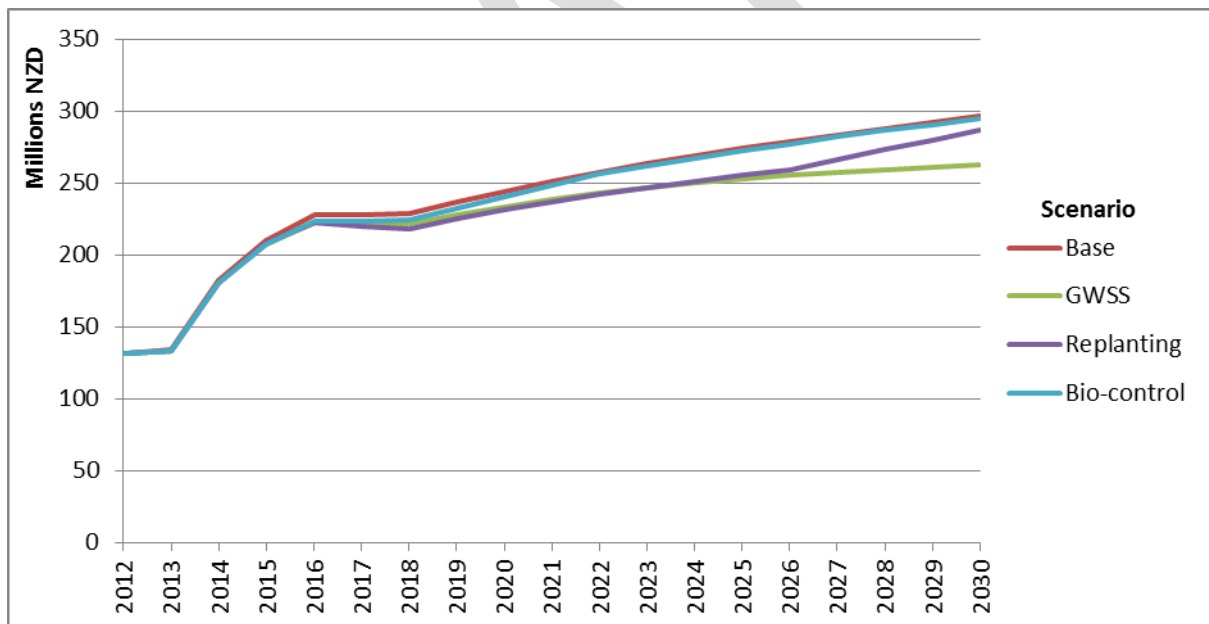


The effects on North Island growers is shown in Figures 7 & 8, and Table 11. The GWSS
creates a steady decline in the profitablity of viticulture over the modelled period. Replanting
creates a sharp decline, losing profitability swiftly as infected vines are uprooted, followed by
a long plateau as the sharpshooter spreads causing additional vineyards to replant their vines.
This period ends in 2026 where sufficient new vines have matured to compensate for areas
still undergoing replanting. From this point the industry quickly recovers, although it will not
reach base levels due to the continued incurred capital costs of replanting.

**Figure 7: The impact of the glassy-winged sharpshooter on North Island viticulture profits until 2030**
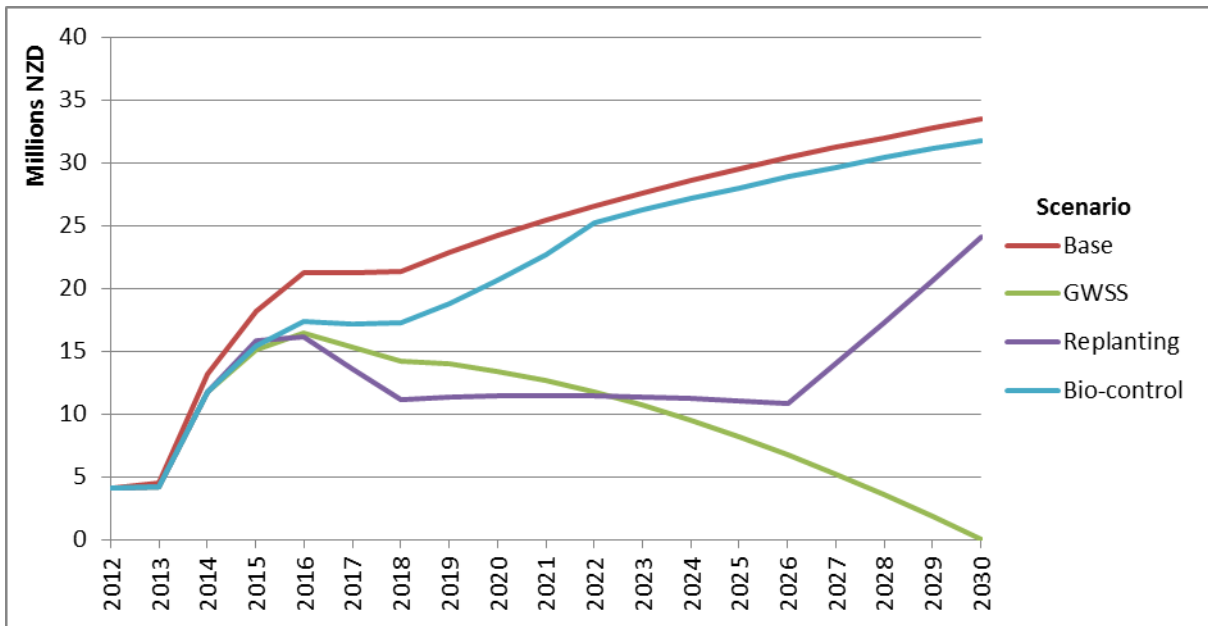


**Table 11: Total change in viticulture profits 2012-2030, for the glassy-winged sharpshooter scenarios**

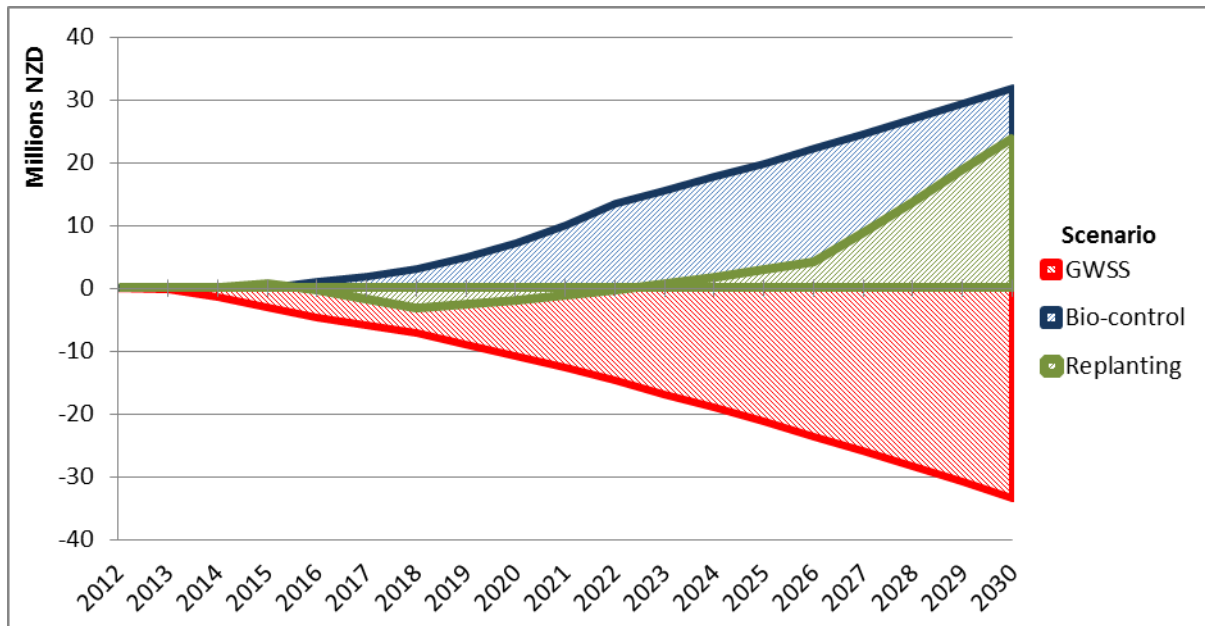|  | Total (milNZD) | Mitigation (milNZD) |
|---|---|---|
| **Glassy-winged sharpshooter** | -88.72 | - |
| **Replanting** | -76.65 | 12.07 |
| **Biological control** | -19.45 | 69.27 |

**Figure 8: Total loss and mitigation in viticulture profits 2012-2030, for the glassy-winged sharpshooter scenarios**



The first response modelled for the advent of the GWSS was replanting affected vineyards. This is found to be ineffective for mitigation in the modelled period. Two additional considerations should be made regarding this response. First, is that over a longer period of modelling it would eventually be a profitable option if vineyards can remain in operation without production for the four years needed for new vines to mature. Second, there is no guarantee that secondary incursions of the GWSS and PD could not occur. With this in mind this recovery option is higly unsatisfactory, with high capital costs, risk of future infection and a four-year regrowth period without production for affected vineyards.

Table 12 shows the change in profits annuitized over the modelled period, here glassy-winged sharpshooter causes losses of almost 4 million NZD per hectare.The biological control response, *G. ashmeadi,* given the assumed rates of parasitism, mitigates over 85% of these losses.

**Table 12: Total change in viticulture profits annuitized, for the glassy-winged sharpshooter scenarios**

| | Total (milNZD) | Mitigation (milNZD) |
|---|---|---|
| **Glassy-winged sharpshooter** | -4.93 | - |
| **Replanting** | -4.26 | 0.67 |
| **Biological control** | -1.08 | 3.85 |

458

459

460   Table 13 shows the change in annuitized viticulture profits by hectare. The GWSS on average
461   costs North Island viticulture $620.08 per hectare. Replanting vineyards over the modelled
462   period mitigates on average almost $95 per hectare, although with future costs incurred. The
463   biological control is most effective mitigation response over the modelled period, saving
464   almost $550 per hectare per year in otherwise sustained losses.

465

466   **Table 13: Total change in viticulture profits annuitized per hectare, for the glassy-**
467   **winged sharpshooter scenarios**

|  | Total (NZD) | Mitigation (NZD) |
|---|---|---|
| **Glassy-winged sharpshooter** | -620.08 | - |
| **Replanting** | -535.72 | 84.37 |
| **Biological control** | -135.95 | 484.13 |

468

469   **Conclusions**

470   Biological control is a pivotal component of modern, science-led bioprotection. The broader
471   literature suggests biological control of pests, weeds and plant diseases can be elegant,
472   persistent, non-polluting and inexpensive, as well as conferring on businesses distinct
473   marketing advantages. In fact, the benefit:cost ratios of many biological control successes
474   have exceeded 300:1 (Gurr et al., 2012; Wratten et al., 2013). The analysis presented here
475   takes a well-established New Zealand pest, a weed of which the importance is increasing and
476   a serious insect pest that has reached the Pacific Islands and is expected here imminently. The
477   analysis examines management options for these organisms, including biological control.
478   Using resource-economics modelling techniques, the work shows that, taking selected
479   internal and external factors into account, biological control is considered the most beneficial
480   present and future option. The many negatives of persistent use of insecticides and herbicides
481   are well known. To this should be added the fact that the rate of production of new pesticide
482   molecules is currently at its lowest rate for 30 years.

483

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