Improving sustainable lifetime performance of pastures:

Learning from extreme climatic events

MAF Technical Paper No: 2011/18

Prepared for Ministry of Agriculture and Forestry
By AgResearch and Landcare Research (C10X0825)
February 2010

Authors: Tozer K, Barker G, Cameron C, Yates L, Rahman A

ISSN 2230-2794 (online)
ISBN 978-0-478-37577-0 (online)

March 2011

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

BIOSECURITY NEW ZEALAND

NEW ZEALAND FOOD SAFETY AUTHORITY

Disclaimer

The information in this publication is not government policy. While every effort has been made to ensure the information is accurate, the Ministry of Agriculture and Forestry does not accept any responsibility or liability for error of fact, omission, interpretation or opinion that may be present, nor for the consequences of any decisions based on this information. Any view or opinion expressed does not necessarily represent the view of the Ministry of Agriculture and Forestry.

Publisher

Ministry of Agriculture and Forestry
PO Box 2526
Pastoral House, 25 The Terrace
Wellington 6140
www.maf.govt.nz

Telephone: 0800 008 333

Facsimile: +64 4 894 0300

Improving Sustainable Life-time Performance of Pastures: Learning from Extreme Climatic Events

C10X0825

Short-title:

Climate Change and Pasture Performance

New Zealand's science. New Zealand's future.

Authors: K. Tozer[1], G. Barker[2], C. Cameron[1], Linda Yates[1] & Anis Rahman[1]

Date: 23/2/10

Report for SLMACC

1: AgResearch Ltd

2: Landcare Research

CONTENTS

1. EXECUTIVE SUMMARY 3
2. BACKGROUND 4
3. METHODS 5
   3.1 Trial sites 5
   3.2 Samplings and assessments 5
   3.3 Statistical analyses 6
4. RESULTS AND DISCUSSION 7
   4.1 Objective 1 results: Milestone 1 (Selection of Sites) & Milestone 2 (Pasture Composition Surveys). 7
   4.2 Objective 2 Milestone 1 results: Relationship between pasture diversity, weed presence, pasture performance and management variables 8
   4.3 Objective 3 Milestone 1 results: Impact of pasture performance on farm profit 10
   4.4 Discussion 11
5. RECOMMENDATIONS 14
6. ACKNOWLEDGEMENTS 14
7. REFERENCES 14
8. APPENDIX 1: Farmax DairyPro Report 16

Modelling the Effects of Including Chicory in a Pasture Mix 16
   1. Executive Summary 16
   2. Farmax Models 16
      2.1 Farm Inputs 16
      2.2 Model Outputs 19
   3. Conclusion 24
9. APPENDIX 2: 17 Australasian Weeds Conference submitted paper 26

1. EXECUTIVE SUMMARY

With projected increases in temperature, and incidences of droughts and floods, pastures will become more vulnerable to weeds. Poor pasture persistence is likely to become an increasingly significant issue. There is evidence that increasing diversity of sown pasture species can increase pasture resilience and resistance to invasion of weeds under different climatic conditions. The hypothesis we tested was: can increasing diversity of sown species reduce ingress of unsown species as pastures age? To test this hypothesis, we undertook an on-farm study in different regions throughout New Zealand to investigate the relationships between sown functional diversity, pasture age and ingress of unsown species. Waikato's once in a hundred year drought (2007-08) followed by an extremely wet winter (2008), also provided us with a unique opportunity to assess the impact of these extreme climatic events on between-year shifts in botanical composition.

Thirty paddocks were selected in each of 4 regions: Northland (sheep, beef), Waikato (dairy), Taranaki (dairy) and North Canterbury (sheep, beef, deer), which ranged in age and in the sown mix (grasses + legumes vs. grasses + legumes + herbs). Our reasoning was that as most pastures comprise perennial grasses and perennial legumes, a key means of increasing functional diversity was through sowing the herbaceous species chicory (*Cichorium intybus* L.) and / or plantain (*Plantago lanceolata* L.), which are drought tolerant and provide useful summer feed. In each paddock, we assessed the botanical composition and dry matter content of the different pasture species. Endophyte presence and soil nutrient status was also assessed in a subsample of paddocks within each region. In addition, we compared Waikato botanical composition data between years (during the drought in Feb 2008 and after the drought in Feb 2009) to determine if increasing sown diversity reduced weed ingress. Pasture botanical composition was further assessed in Waikato paddocks every 3 months (summer, autumn, winter and spring) to determine if increasing diversity reduced weed ingress.

There was evidence that increasing species diversity improved persistence of sown species in Northland, thus reducing the ingress of unsown species. This was further supported by the trend in Waikato pastures, inferring that increasing diversity may help to reduce weed ingress after severe climatic events, such as the severe Waikato drought.

Farmax DairyPro modelling also indicated that including a sown herb such as chicory in the pasture has the potential to provide high quality feed at a time of year when pasture growth is generally slow and of low quality. The models identified an increase in operating profit of $161/ha when chicory is included in the pasture mix. This increase in operating profit occurred due to a reduction in the use of high energy imported supplementary feed.

In all regions except for Taranaki, sown species declined and unsown species increased over time. This was mainly due to an increase in unsown grasses, although unsown herbs also increased. There was little unsown legume. Further analyses are presently underway to investigate the relationship between weed ingress and sown pasture diversity, based on a literature review of plant functional traits.

While sown herbs such as chicory and plantain show promise in increasing pasture resilience, research is required to develop optimal management strategies for these species. Given that pasture persistence was the most frequently mentioned concern of the farmers interviewed to obtain farm management information, innovative ways of increasing pasture persistence and resilience must be investigated, if pastures are to be profitable and perform well in a changing climate.

2. BACKGROUND

With projected increases in temperature, and incidences of droughts and floods, pastures will become more vulnerable to weeds (Kenny 2001). Weeds formerly restricted by cooler temperatures will be able to survive and reproduce in more southerly regions and at higher altitudes (Bourdôt *et al.* 2007). Subtropical grasses such as the C_4 yellow bristle grass (*Setaria pumila*) are of particular concern given the projected warming trend and subsequent potential spread. Further, there is concern that cool season C_3 grasses (e.g., winter grass *Poa annua,* barley grass *Critesion* spp.) may become more aggressive with projected climate scenarios (Kenny 2001; Bourdôt *et al.* 2007; Zhang *et al.* 2007; Wratt *et al.* 2008). Weedy grasses comprise 25% of the total number of species recognized as pastoral weeds and are very difficult to manage in intensive pastures as there are few selective grass herbicide options available (Bourdôt *et al.* 2007). Weeds also have the potential to alter subsequent plant community structure by hosting invertebrates which may then switch to temperate sown species (Campbell *et al.* 1996 and references therein).

Given the potential impact of projected increases in extreme weather events on plant interactions between weeds and pests in pastures, poor pasture persistence is likely to become an increasingly significant issue, as identified the Pasture Renewal Charitable Trust (2008). Pasture persistence has also been identified as a key issue in dairy, beef and sheep industries. Lack of persistence of sown species and ingress of weedy species can lead to significant production loss (Bourdôt *et al.* 2007). In addition, renovation costs are high. For example, it has been estimated that full renovation of a dairy paddock is well in excess of \$1000 ha^{-1}, taking into account all costs (Bay of Plenty dairy farmer, personal communication).

It has been demonstrated that increasing diversity of plant species in grassland communities can increase pasture resilience and resistance to invasion by exotic species (Sanderson *et al.* 2004) under different climatic conditions. Often, it is the species identity that is most important, rather than the number of species *per se* (Crawley *et al.* 1999). This is related to their functional complementarity, or ability to respond to climatic factors in different ways to other species in the mix. Plants can therefore be classified according to their functional traits (e.g. perennial temperate grasses, perennial legumes, etc).

In New Zealand, given that most pastures comprise perennial grasses and perennial legumes, a key means of increasing functional diversity is through sowing the herbaceous species chicory (*Cichorium intybus* L.) and plantain (*Plantago lanceolata* L.), which are drought tolerant and provide useful summer feed.

The hypothesis we tested was: can increasing functional diversity of sown species reduce ingress of unsown species as pastures age? To test this hypothesis, we undertook an on-farm study in different regions throughout New Zealand to investigate the relationships between sown functional diversity, pasture age and ingress of unsown species.

Waikato's once in a hundred year drought (2007-08) followed by an extremely wet winter (2008), also provided us with a unique opportunity to assess the impact of these extreme climatic events on between-year shifts in botanical composition and forage quality. Average annual rainfall in Hamilton (1975-2004) during November, December, January and February was 93.8, 98.2, 85.3 and 75.3 mm respectively. This is in contrast to the monthly rainfall from November 2007–February 2008, which was much lower: 51.2, 71.8, 4.4 and 26.8 mm between November and February respectively.

Statistical procedures were used to establish relationships between these data and farm management / paddock history for the Waikato sites. It was envisaged these relationships will enable us to identify potential pasture mixtures and species which are most resilient and persistent as well as optimal management practices required for persistence. In addition, pasture performance data were used in the newly released version of Farmax Dairy, an agricultural systems decision support tool, to determine the impact of pasture performance on farm profitability. This was expected to give us a potential indication of the impact of climate change on whole farm systems.

3. METHODS

3.1 Trial sites

Thirty paddocks were selected in each of 4 regions: Northland (sheep, beef), Waikato (dairy), Taranaki (dairy) and North Canterbury (sheep, beef, deer, Figure 1). These regions varied in climate, from Northland with mild winters and warm, subtropical summers which favour C4 summer-active species, to North Canterbury, which has a much harsher climate of hot dry summers and cold winters (Table 1). Paddocks were selected such that they ranged in age since renovation and in functional diversity of the sown mix (grasses + legumes vs. grasses + legumes + herbs). In addition, paddocks were only selected if: 1) farmers possessed good paddock history records (i.e., species, and cultivars sown, rates, seed coating, endophyte status, sowing date and method); 2) they were not irrigated (other than effluent spreading on a small number of dairy paddocks); and 3) no under or oversowing had occurred since renovation. Paddock sizes varied considerably, although most dairy paddocks were approximately 1.5 ha and most beef and sheep paddocks were several hectares in size. Two to three paddocks were randomly selected on each farm, equating to 10-15 farms in each region.

3.2 Samplings and assessments

Assessments took about one week in each region and were undertaken during spring 2009. In each paddock, botanical assessments were undertaken in a 1 hectare area. Percent cover of species present was assessed in 4, randomly placed 2 x 2 m quadrats.

Percentage of total dry matter was assessed in 20, 0.1 m^2 quadrats in each paddock, using the BOTANAL method (Jones and Hargreaves 1979). This method visually ranks the 3 most dominant vegetation classes present in a quadrat, with respect to their dry matter contribution. Standard multipliers are then used to estimate the contribution of these vegetation classes to total pasture dry matter. Total dry matter was determined using a platemeter (Stockdale and Kelly 1984), calibrated using quadrat cuts.

Assessments were undertaken for sown and unsown grasses, legumes and herbs. Sown grasses in these sites included perennial ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), cocksfoot (*Dactylis glomerata* L.), prairie grass and grazing bromes (*Bromus* spp.), timothy (*Phleum pretense* L.) and phalaris (*Phalaris aquatic* L.). The sown legumes included white clover (*Trifolium repens* L.), red clover (*T. pretense* L.), subterranean clover (*Trifolium subterraneum* L.), lucerne (*Medicago sativa* L.) and lotus (*Lotus* spp.), while sown herbs included chicory and plantain.

Average maximum and minimum air temperature, soil temperature and annual rainfall data were obtained for the life-time of each pasture (i.e. average data for the period between spring 2009 and the year in which the pasture was sown). These data were obtained using the Virtual Climate Station database (Tait *et al.* 2006; Cichota *et al.* 2008).

Management variables were documented during discussions with farmers prior to undertaking field assessments. Information obtained included: sowing method (direct drilling or cultivation), herbicide application during sowing, species and cultivars sown, sowing rates, endophyte status, presence or absence of seed coating of sown seed and soil nutrient levels. Most farmers used coated seed, herbicide during renovation and direct-drilled. Soil test results were more variable, as was the endophyte status of sown perennial grasses. Endophyte status was determined using the tissue-print immunoblot procedure (Hahn *et al.* 2003). While this technique only tests for presence or absence of endophyte, presence of the fungal endophyte indicates that the sown species will be resistant, at least in part, to insect attack. As farmer soil tests results were nearly always pooled over several paddocks, soil samples were taken during the survey from a subsample of 18 paddocks (3 from each treatment) and analysed through NZLABS, Hamilton, for calcium, potassium, magnesium, sodium, organic carbon, organic matter, phosphorus, pH and sulphur levels.

The impact of pasture performance on profitability was assessed with Farmax DairyPro (version 6.3.67.3), which was used to develop models for Waikato pastures with and without chicory. The model used chicory quality data, which was obtained from sampling chicory in Waikato pastures during spring, from the farm on which the modelling was based.

3.3 Statistical design and analyses

There were two treatments: functional diversity and age. Of the 30 paddocks in each region, 15 paddocks were selected in which grasses and legumes had been sown (2 functional groups), and 15 paddocks in which grasses, legumes and herbs had been sown (3 functional groups). In each region, the 15 paddocks in each category were further subdivided into 'young' (renovated in the last 1-3 years), medium (4-6 years) and 'old' (7 years or more). However, in Northland, it was not possible to locate sufficient renovated paddocks with good paddock histories that were over 6 years old. Therefore, young was defined as 1-2 years, medium as 3-4 years and old as 5-6 years. This gave approximately 5 paddocks for each age and diversity category within each region.

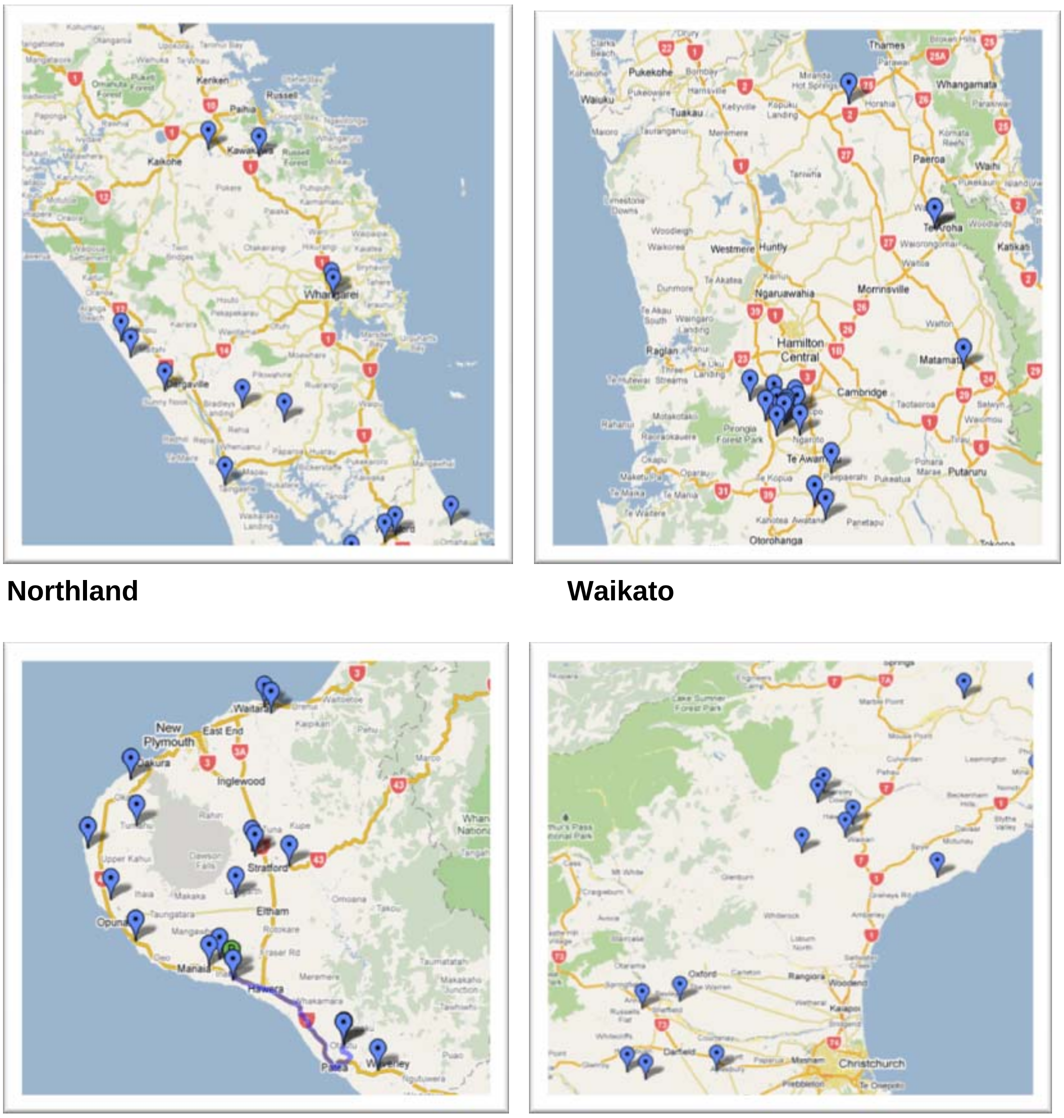
REML was undertaken using GenStat 10.2 (VSN International Ltd., Oxford), with farm as a random effect, on the proportion of total dry matter and percent cover of the different vegetation classes present, including total sown and unsown species, and sown and unsown grasses, legumes and herbs. Further analyses using principal axis correlation are underway, combining data collected during this project with insect data being collected from these field sites for the associated project: SFF 09-088.

4. RESULTS AND DISCUSSION

4.1 Objective 1 results: Milestone 1 (Selection of Sites) & Milestone 2 (Pasture Composition Surveys).

Field sites were selected as planned to undertake the botanical assessments (Figure 1). Site selection and botanical surveys were undertaken are described in the methods section above.

Key climatic variables were also tabulated for the different regions (Table 1). A decline in the average, minimum temperature and soil temperature was evident as the regions become more southerly (i.e., from Northland to Canterbury). Average annual rainfall over the life-time of the pastures was greatest in Taranaki (1796 mm) and lowest in Canterbury (800 mm).



Northland **Waikato**

Taranaki **North Canterbury**

Figure 1". Sites selected in each of the four regions.

Table 1. Key climatic variables. The annual, average maximum and minimum temperatures (^oC), rainfall (mm) and soil temperature (^oC), averaged over all sites within each region. Means with different subscripts are significantly different ($P < 0.001$).

	Northland	Waikato	Taranaki	Canterbury	Region SED
Max temp	19.0_c	19.2_c	16.7_a	17.3_b	0.18
Min temp	11.4_c	9.0_b	9.0_b	6.5_a	0.26
Rainfall	1463_{bc}	1277_b	1796_c	799_a	205.0
Soil temp	15.0_d	14.3_c	12.8_b	10.8_a	0.15

Table 2. Soil nutrient levels in Northland, Waikato, Taranaki and North Canterbury. All levels are expressed as MAF quick test units, except for Olsen Phosphate, µg/ml and sulphate sulphur, ppm. OC: organic carbon, OM: organic matter.

Nutrient	Northland	Waikato	Taranaki	Canterbury	Region SED
Calcium	15.0	12.9	9.7	15.2	3.23
Potassium	9.1	16.1	9.6	5.9	3.52
Magnesium	35.6	45.3	36.0	32.1	9.10
Sodium	8.9	8.0	9.9	9.2	2.08
Organic carbon	9.8	14.5	10.9	4.3	3.37
Organic matter	16.9	25.0	18.9	7.4	5.82
Olsen P	41.9	52.3	36.2	18.9	10.16
pH	6.2	6.2	6.2	6.3	0.19
Sulfur	16.1	24.2	21.3	5.2	9.32

4.2 Objective 2 Milestone 1 results: Relationship between pasture diversity, weed presence, pasture performance and management variables

Northland sheep and beef: Of the grasses sown with endophyte, 64% of the plants tested as endophyte positive (Table 3). There was no difference between diversity treatments or regions in endophyte infection (Table 3) or soil nutrient levels (Table 2).

Total sown species content was greater in young than old pastures (90, 77 and 69% of total dry matter in young, medium and old pastures respectively). There was no difference between treatments in cover, although the trend was similar (Table 3).

Table 3. Mean percent cover of all sown species (grasses, legumes and herbs) in 'young', 'medium' and 'old' dryland pastures. Means with different subscripts are significantly different ($P = 0.05$). The number of plants infected with endophyte, averaged within each region, is also shown (SED = 13.45 for comparison between regions).

Region	Young	Medium	Old	SED	% endophyte
Northland	84	68	69	7.2	64.1
Waikato	75_a	59	55_b	8.5	71.5
Taranaki	85	81	86	3.5	79.6
Canterbury	78	74	60	9.1	67.3

Sown grass content was higher in young and medium aged pastures, when sown without than with herbs, but was similar in old pastures (young pastures: 81% and 57% of total dry matter, medium pastures: 71% and 46%, old pastures: 53% and 57%, without and with sown herbs respectively, $P < 0.05$). This was due to a decline in sown grass content as pastures aged, when sown without herbs.

Content of unsown species was greater in medium and old than in young pastures ($P < 0.05$). Similar trends were observed for cover, although they were not significant (Table 4). This was primarily due to an increase in unsown herbs, which contributed more dry matter in the old (11%) than young pastures (2%, $P < 0.01$). In addition, ingress of unsown herbs (e.g., buttercup (*Rananculus* spp.), dock (*Rumex* spp.), penny-royal (*Mentha pulegium* L.)) was less (5%) in pasture sown with than without (17%) herbs, but only in old pastures ($P < 0.05$, % of total dry matter). Unsown grass content was not affected by age or by sowing herbs (6, 17 and 18% of total dry matter respectively, in young, medium and old pastures). Unsown legumes contributed little dry matter and pasture cover (Table 4).

Table 4. Mean percent cover of unsown species in 'young', 'medium' and 'old' dryland pastures for North Canterbury, Taranaki and Waikato. Means with different subscripts are significantly different ($P = 0.05$).

Vegetation	Young	Medium	Old	SED
Northland				
Grasses	9	23	14	7.0
Legumes	1	1	1	1.6
Herbs	4	6	9	2.3
Total	14	29	25	7.5
Waikato				
Grasses	6_a	27_b	28_b	8.5
Legumes	0	0	0	
Herbs	9	14	12	3.4
Total	15_a	41_b	41_b	8.6
Taranaki				
Grasses	2	3	2	1.1
Legumes	0	0	0	
Herbs	10	12	10	2.7
Total	12	15	12	3.0
Canterbury				
Grasses	7_a	13	23_b	5.9
Legumes	9	12	9	6.6
Herbs	1_a	1_a	3_b	1.0
Total	15_a	25	38_b	9.7

Waikato dairy: Of the grasses sown with endophyte, 72% of the plants tested as endophyte positive (Table 3). There was no difference between diversity treatments or regions in endophyte infection (Table 3) or soil nutrient levels (Table 2).

Sown species cover in spring 2009 was greater in young (75%) than old pastures (55%, Table 3). Conversely, cover of unsown species in spring 2009 was higher in medium and old (both 41%) than in young pastures (15%, Table 4, $P = 0.05$). This was due primarily to the change in cover of unsown grasses, which were much higher in medium (27%) and old (28%) than in young (6%) pastures ($P = 0.01$). However, there was no change in the cover of unsown herbs, which remained below 14%. There were negligible unsown legumes.

There was no detectable effect of herbs on botanical composition of the pastures when comparing differences in botanical composition between years (February 2008 and 2009). However, it was difficult to obtain data from before the drought. During 2009, there was a consistent trend for pastures sown with herbs to have lower unsown species cover, particularly in May (autumn) and August (winter), although this did not reach statistical significance (Table 5).

Table 5. Mean percent cover of unsown species in Waikato dairy pastures sown with herbs (high diversity) and without herbs (low diversity). 'n' denotes the number of paddocks (sites) surveyed.

Sampling time	High diversity (%)	Low diversity (%)	sed	n
February 2008	22	17	10.9	15
February 2009	28	43	10.6	35
May 2009	17	34	8.0	28
August 2009	11	20	5.6	34
November 2009	27	31	6.9	44

Taranaki dairy: Of the grasses sown with endophyte, 80% of the plants tested as endophyte positive (Table 3). There was also no difference between diversity treatments or regions in endophyte infection (Table 3) or soil nutrient levels (Table 2).

Total sown species cover did not alter with pasture age (mean = 84%, Table 3).

There was no change in cover of unsown species as pastures aged; their total cover remained at 12-15% (Table 4). However, there was less (1%) bare ground in pastures sown with than without herbs (5%, $P = 0.05$).

North Canterbury sheep, beef and deer: Of the grasses sown with endophyte, 67% of the plants tested as endophyte positive (Table 3). There was no difference between diversity treatments or regions in endophyte infection (Table 3) or soil nutrient levels (Table 2).

The dry matter content (% of total dry matter) of sown species was greater in young (87%) and medium (85%) than in old (65%) pastures ($P < 0.05$). A similar trend was evident in % cover but did not reach statistical significance (Table 3).

Cover of unsown species was greater in old than young pastures (Table 4, $P = 0.05$). This was due to an increase in unsown grasses (7, 13 and 23% cover in young, medium and old pastures respectively, $P < 0.05$) and unsown herbs (1, 1 and 3% cover in young, medium and old pastures respectively, $P < 0.05$). There was less bare ground (3%) in pastures sown with than without (12%) herbs, but only when pastures were young ($P < 0.05$).

4.3 Objective 3 Milestone 1 results: Impact of pasture performance on farm profit

Using Farmax DairyPro (version 6.3.67.3), models were developed for Waikato pastures with and without chicory. Modelled pasture growth rates and ME data were sourced from data collected during the study. Base model data were based on a non-renewed paddock, whilst the Plus Chicory model data were based on a paddock sown in autumn 2009 including chicory in the seed mix. Data for the non-renewed paddock were collected between January and November, and supplemented with DairyNZ average pasture growth rate data for the area. Chicory was the only sown herb used in Waikato dairy pastures; none of the pastures surveyed contained plantain (which was often a frequently sown herb in the other regions surveyed).

The modelling was representative of what is expected when chicory proportion in the sward remains high (like in the first year after establishment); results would be expected to change as chicory proportion declines. Significant differences were observed between winter and summer growth rates for the Base and Plus Chicory model. The paddock including chicory in the sward grew slightly more (0.3% increase), but growth rates were proportionately scaled so that both the base and plus chicory models had the same total pasture grown. Metabolisable energy (ME) for the two models were fairly similar until late summer/autumn, where the ME value of the Plus Chicory system was significantly higher than the Base model. It is over the summer/autumn months that the chicory is most actively growing and presents the benefit of high ME values when pasture ME can be less than adequate to meet animal demand.

The lactation curves for the two models were very similar as the cows produced the same amount of milksolids in the two models. With the higher ME of the available pasture in autumn, the cows in the Plus Chicory model were able to produce more milksolids at a time where production was generally tapering off. The cows in the Plus Chicory model achieved the same level of milksolids production with less feed, and therefore have a higher feed conversion efficiency.

The Base model pasture cover starts & ends the season with a much higher cover than the Plus Chicory model. This results in the Plus Chicory model being more reliant on supplementary feeds to meet animal demand over the dry period (i.e., when cows are not lactating), whereas the lower growth rate in summer for the Base model results in this system being more reliant on supplementary feeds during this period to keep the cows milking. From March onwards the Plus Chicory growth rates are below the Base model, and to ensure the pasture cover is adequate for the dry period intake of pasture needs to be managed with provision of supplementary feed.

As a result of variations in pasture growth rates and metabolisable energy both systems feed supplementary feed out all year. In the Base model imported supplementary feed is fed out for the majority of the year, in addition to conserved pasture silage being fed out during the dry period and summer grown turnips being fed in late summer/autumn. This supplementary feed is required to meet animal demands due to lack of pasture growth and low quality pasture. In the Plus Chicory system pasture growth rates over the dry period are reduced, which creates the need for further supplementation during the dry period with imported maize silage. The higher growth rates over summer in the Plus Chicory system reduce the need for supplementation, and in autumn the higher ME compensates for the reduction in growth, further reducing the need for supplementation.

The Plus Chicory model was found to increase operating profit per hectare by $161. This increase in operating profit is due to the reduction in imported supplement (palm kernel). The high quality feed available during autumn and the subsequent drop in requirement for high energy supplementation in the Plus Chicory model reduces the reliance on imported supplementary feed and the associated risks of variation in feed prices and availability. This saving may be more marked in a dry summer/autumn when chicory is still able to grow, when its large tap root can source water from deeper in the soil profile, and supplementary feed prices rise due to the high demand.

The greatest benefit from including chicory in the pasture sward is from the increase in growth over the summer period and the higher ME of the pasture, particularly in the late summer/autumn period. This benefit is likely to be even more marked during a summer dry season when chicory can sustain growth much longer than grass. The increased growth and ME of the pasture allows cow numbers to be maintained whilst milking on further into autumn, or reduces the use of any imported supplements. With the higher energy, cows are able to potentially produce more or milk longer into the autumn, and could finish in better condition, reducing the need for large weight gain over the dry period.

Please see Appendix 1 for details of this work, including graphs of the model output.

4.4 Discussion

A reduction in sown species and increase in unsown species was evident in all regions as pastures aged, except in Taranaki. Most pastures assessed in this study were less than 10 years old, and in Northland, all were less than 6 years old. Yet in Waikato, unsown species cover had reached 41% within 4 – 6 years of sowing and 25% in North Canterbury.

Ryegrass appeared to persist well, although it was not possible to detect if the cultivars sown were actually the cultivars present when the paddocks were surveyed.

Timothy and prairie grass were less frequently sown and did not appear to persist. Cocksfoot however, was more persistent in some regions, such as North Canterbury.

There was evidence that increasing species diversity improved persistence of sown species in Northland, thus reducing the ingress of unsown species. This was further supported by the trend in Waikato pastures, inferring that increasing diversity may help to reduce weed ingress after severe climatic events, such as the severe Waikato drought. This concurs with other studies, in which increasing functional diversity increased resilience (Dodd *et al.* 2004). This also concurs with anecdotal evidence provided by farmers interviewed during this project. A number of the farmers observed that sowing a combination of species that were adapted to a range of environmental conditions (e.g. winter-active species such as ryegrass or bromes and summer-active or more drought tolerant species such as lucerne or cocksfoot) improved pasture persistence and lessened the ingress of undesirable species, (e.g., Californian thistle *Cirsium arvense* (L.) Scop.; barley grass *Hordeum murinum* L.). Overall however, we only detected weak relationships between sown functional diversity and unsown species ingress. It may be that the functional diversity was insufficient for effects to be detectable, especially as sown herbs comprised a small amount of the pasture cover and content. Further, the classification we chose (grasses + legumes vs. grasses + legumes + herbs) may be too simplistic to detect benefits of functional diversity. Further analyses are in progress using principal axis correlation methods to better understand relationships between sown diversity and pasture botanical composition.

While sown species composition can affect weed abundance, maintaining an even distribution of forage species is also important. In an American grazed field study, species evenness was negatively correlated to weed abundance over two consecutive years (Tracy *et al.* 2004).

The identity of unsown species in this study varied between regions, although winter grass (*Poa annua* L.) was prevalent in all regions. C4 grasses, such as kikuyu (*Pennisetum clandestinum* Hochst. Ex Chiov.) was detected in Northland, while temperate species such as browntop (*Agrostis capillaries* L.), barley grass and vulpia (*Vulpia* spp.) were more prevalent in Canterbury. Unsown species were often undesirable, as farmers viewed them as less productive, less palatable and of poorer forage quality, especially during seed maturation. In addition, seeds of some of the species observed can damage hides or carcasses of grazing livestock (e.g. vulpia, barley grass, storksbill (*Erodium* spp.) (Dowling *et al.* 2000).

In addition to weedy undesirable species, some unsown species were productive, such as ryegrass, subterranean clover or commercial cultivars of plantain. Ryegrass was documented in many pastures in which it was not sown, in small amounts. For example, ryegrass was the dominant species present (> 50% of total dry matter) in one 4 year old Waikato paddock, which was sown with tall fescue and established well in its first year. Therefore, it is also likely that old varieties of ryegrass were present in pastures where newer cultivars of ryegrass were sown (Burggraaf and Thom 2000). Ingress of older ryegrass cultivars would result in an over-estimation of sown grasses and under-estimation of unsown grasses, as it was not possible in the field to identify different ryegrass cultivars. Further work is underway to test for endophyte identity of the ryegrass present, which will enable us to determine how well the sown ryegrass cultivars are persisting.

Commercial cultivars of plantain were likewise found in small quantities where it had not been sown. This occurred in all regions assessed. Farmers observed that plantain appeared to self-seed readily and to establish in stock dung. Plantain was usually present in 'old' pastures in which it was sown, in contrast to chicory, which appeared to be less persistent. Plantain may show more promise than chicory in preventing the ingress of unsown species.

While obtaining paddock history information from farmers, concerns regarding management of herbs were frequently raised. This included how best to graze them to maximise their persistence and also how to control the broad-leaved weeds in a pasture containing herbs. This was due to most broad-leaved herbicides killing the sown herbs, as well as unsown broadleaved weeds.

Ingress of unsown species and persistence of sown species varied between regions; further analyses are underway to quantify these differences. Variation may reflect differences in climate, as well as in enterprise (sheep vs. dairy etc). For example, Taranaki tended to have the highest proportion of sown species in the pastures, while Waikato, Northland and North Canterbury had greater ingress of unsown species. In Taranaki, average maximum temperature (17^{o}C) and rainfall (1604 mm) in years in which pastures were sown would favour establishment of ryegrass, the dominant sown grass. In comparison, mean Canterbury rainfall in the years in which pastures were sown was much lower (789 mm) and the average soil temperature over the life-time of the pastures was also lower (10.8 ^{o}C, Table 1) than in Taranaki. Rainfall in Taranaki over the life-time of the pastures was also higher (1799 mm) than in Canterbury (800 mm).

Also, there were numerous summer droughts over the last decade in Canterbury, which would reduce vigour of sown species and favour winter-active annual grasses, such as vulpia, winter grass and barley grass, which avoid the summer drought. These differences between regions give insights into how pastures may perform as regional climates change.

Climatic differences would lead to differences in insect populations in the regions, which in turn greatly influence pasture persistence and performance. Northland farmers in particular frequently mentioned difficulties with pasture persistence associated with high insect pest levels. While pest insect sampling was beyond the scope of this study, data on insect populations at these sites are being collected and will be analysed through an associated project, SFF 09-088. As part of the SFF project, we will also be undertaking further endophyte analyses, to detect if the sown, novel endophytes are persisting or if wild-type endophyte is re-invading. Appropriate use of endophyte can reduce damage of key insect pests and improve pasture performance and persistence. With future changes in climate and potentially greater insect pest pressure, endophyte will become a key a management tool to improve pasture persistence.

A further key management tool, which can interact with climate, is fertiliser application. Soil nutrient status can have a huge impact on vigour of sown species and the ingress of weeds. As farmers chosen in this study were actively involved in their prospective industries, it is likely that they were above average with respect to their management and fertilised their pastures well. This may explain why soil nutrient status was generally high, particularly in Waikato and Taranaki dairy pastures. Soil nutrient levels also did not differ between the diversity treatments. Analyses are currently in progress to combine insect data (collected from the same field sites in SFF 09-088) with management and botanical data collected in this project, to better understand relationships between pasture persistence, management and climate.

While there is only limited evidence for the hypothesis that increasing functional diversity (by including herbs) reduces ingress of unsown species, these results give us valuable insight into persistence of sown species and ingress of unsown species. Currently, we are further testing this hypothesis relating to functional diversity, under controlled conditions, in replicated field plots, through a sustainable farming fund grant (SFF 09-088). In combination with results from the present study, we can better ascertain the role and potential benefits of functional diversity on pasture persistence and weed ingress in New Zealand pastures.

Other benefits of increasing functional diversity also became evident during this project. In addition to increasing resilience under different climatic conditions, including herbs such as chicory in the pasture mix can increase profitability. Chicory results in the following effects:

- Variation in the distribution of pasture growth throughout the year, and
- Variation in supply of metabolisable energy throughout the year.

The incorporation of chicory in a sward has the potential to provide high quality feed at a time of year when pasture growth is generally slow and of low quality. The models identified an increase in operating profit of $161/ha when chicory is included in the pasture mix. This increase in operating profit occurred due to a reduction in the use of high energy imported supplementary feed, due to chicory providing good quality forage and improved pasture performance at critical times.

5. RECOMMENDATIONS

- Pasture persistence differs dramatically between regions, with more northern regions such as Northland and Waikato showing greater unsown weed ingress than cooler regions such as Taranaki.
- Increasing functional diversity by including herbs (chicory, plantain) in pastures can reduce invasion of broad-leaved weeds to a limited extent. Herbs also improve pasture performance by providing feed when ryegrass-based pastures are generally slow and of low quality. The commercial variety of plantain also shows promise as a persistent herbaceous species in a range of climates.
- Management of herbaceous species needs more research, to ensure their persistence.
- Controlled studies are required to more clearly ascertain the relationships between functional diversity and persistence. These are currently underway in a SFF project, 09-088.
- Poor pasture persistence was the most frequently mentioned concern of the farmers interviewed. Innovative ways of increasing pasture persistence and resilience must be further investigated, if pastures are to be profitable and perform well in a changing climate.

6. ACKNOWLEDGEMENTS

We gratefully acknowledge the Ministry of Agriculture and Forestry (SLMACC CONT-20257-SLMACC-AGR) for providing funding to undertake this research. Many thanks are also due to farmers and industry personnel who kindly gave their time. DairyNZ, Environment Waikato and Environment Bay of Plenty provided co-funding for this project. Nadine Loick, Derrick Wilson, Mike Trolove, Shona Lamoureaux and Yuki Fukuda gave invaluable assistance with collection of field data and the final report.

7. REFERENCES

Bewsell D, Botha N, Brown M, Fraser T, Wilson J (2008) Understanding pasture renewal in New Zealand. Report on market research for the Pasture Renewal Charitable Trust.

Bourdôt GW, Fowler SV, Edwards GR, Kriticos DJ, Kean JM, Rahman A, Parsons AJ (2007) Pastoral weeds in New Zealand: status and potential solutions. *New Zealand Journal of Agricultural Research* **50**, 139-161.

Burggraaf VT, Thom ER (2000) Contamination and persistence of endophyte-free ryegrass pastures established by spray-drilling, and intensively grazed by dairy cows in the Waikato region of New Zealand. *New Zealand Journal of Agricultural Research* **43**, 163-173.

Campbell BD, Wardle DA, Woods P, Field TRO, Williamson DY, Barker GM (1996) The ecology of subtropical grasses in temperate pastures: an overview. *Proceedings of the New Zealand Grassland Association* **57**, 189-197.

Cichota R, Snow VO, Tait AB (2008) A functional evaluation of virtual climate station rainfall data. *New Zealand Journal of Agricultural Research* **51**, 317-329.

Crawley MJ, Brown SL, Heard MS, Edwards GR (1999) Invasion-resistance in experimental grassland communities: species richness or species identity? *Ecology Letters* **2**, 140-148.

Dodd MB, Barker DJ, Wedderburn ME (2004) Plant diversity effects on herbage production and compositional changes in New Zealand hill country pastures. *Grass and Forage Science* **59**, 29-40.

Dowling PM, Michalk DL, Sindel BM (2000) Weed management in pasture systems. In 'Australian weed management systems'. (Ed. BM Sindel) pp. 306-328. (R.G. and F.J. Richardson: Meredith, Victoria, Australia).

Hahn H, Huth W, Schöberlein W, Diepenbrock W (2003) Detection of endophytic fungi in Festuca spp. by means of tissue print immunoassay. *Plant Breeding* **122**, 217-222.

Jones RM, Hargreaves JNG (1979) Improvements to the dry-weight-rank method for measuring botanical composition *Grass and Forage Science* **34**, 181-189.

Kenny GJ (2001) Climate Change: Likely Impacts on New Zealand Agriculture. A report prepared for the Ministry for the Environment as part of the New Zealand Climate Change Programme.

Sanderson MA, Skinner RH, Barker DJ, Edwards GR, Tracy BF, Wedin DA (2004) Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Science* **44**, 1132-1144.

Stockdale CR, Kelly KB (1984) A comparison of a rising-plate meter and an electronic capacitance meter for estimating the yield of pastures grazed by dairy cows. *Grass & Forage Science* **39**, 391-394.

Tait A, Henderson R, Turner R, Zheng Z (2006) Thin plate smoothing interpolation of daily rainfall for New Zealand using a climatological rainfall surface. *International Journal of Climatology* **26**, 2097-2115.

Tracy BF, Renne IJ, Gerrish J, Sanderson MA (2004) Effects of plant diversity on invasion of weed species in experimental pasture communities. *Basic and Applied Ecology* **5**, 543-550.

Wratt D, Mullan B, Dean S, Hollis M, Allan S, Williams T, Kenny GJ (2008) Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand - 2nd Edition. Ministry of the Environment.

Zhang B, Valentine I, Kemp PD (2007) Spatially explicit modelling of the impact of climate changes on pasture production in the North Island, New Zealand. *Climatic Change* **84**, 203-216.

8. APPENDIX 1: Farmax DairyPro Report

Modelling the Effects of Including Chicory in a Pasture Mix

Linda Yates

1. *Executive Summary*

Using Farmax DairyPro (version 6.3.67.3) models were developed for both with and without chicory. Including chicory in the pasture mix results in the following effects:

- Variation in the distribution of pasture growth throughout the year, and
- Variation in supply of metabolisable energy throughout the year.

The incorporation of chicory in a sward has the potential to provide high quality feed at a time of year when pasture growth is generally slow and of low quality. The models identified an increase in operating profit of $161/ha when chicory is included in the pasture mix. This increase in operating profit occurred due to a reduction in the use of high energy imported supplementary feed.

2. *Farmax Models*

2.1 Farm Inputs

The base farm model was loosely based on a combination of DairyNZ systems levels 3 & 4, adapted to fit with actual pasture growth data. The basic farm system information is presented in Table 1. This was a spring calving system, which utilised winter grazing off (25% for 6 weeks) and supplements (conserved pasture silage, summer grown turnips, and imported maize silage and palm kernel).

Table 1 Physical Summary for Base Model and Plus Chicory Model.

	Base Model	***Plus***
Performance		
Effective Area ha	100	100
Cows Numbers (1st July)	320	320
Milk Solids kg total	112888	112873
Milk Solids kg/ha	1129	1129
kg MS/cow	358	358
Peak Cows Milked	315	315
Days in Milk	273	272

Avg. BCS at calving	5	5.1
Live Wt /ha	1293	1288
kg MS /kg cow (%)	87.3	87.6
kg DM eaten /kg MS	13.1	12.6
Feeding		
Pasture Eaten tDM/ha	9.92	9.86
Forage Crops tDM/ha	2.35	2.45
Conserved Feed tDM/ha	0.38	0.38
Bought-in Feeds tDM/ha	0.31	0.18
Total Feed Eaten tDM/ha	14.43	13.88
% Total Supplements / Feed Eaten	31.3	29
% Bought Feed / Feed Eaten	2.2	1.3

Modelled pasture growth rates and ME data was sourced from data collected during the study. The Base model data was based on a non-renewed paddock, whilst the Plus Chicory model data was based on a paddock sown in autumn 2009 including chicory in the seed mix. Data for the non-renewed paddock was collected between January and November, and supplemented with DairyNZ average pasture growth rate data for the area. In addition ME values obtained from the renewed paddock were substituted for the missing months (Dec-Feb). The pasture growth rates and ME of the pasture for both models are presented in Figures 1 & 2 respectively. This modelling is representative of what is expected when chicory proportion in the sward remains high (like in the first year after establishment); results would be expected to change as chicory proportion declines.

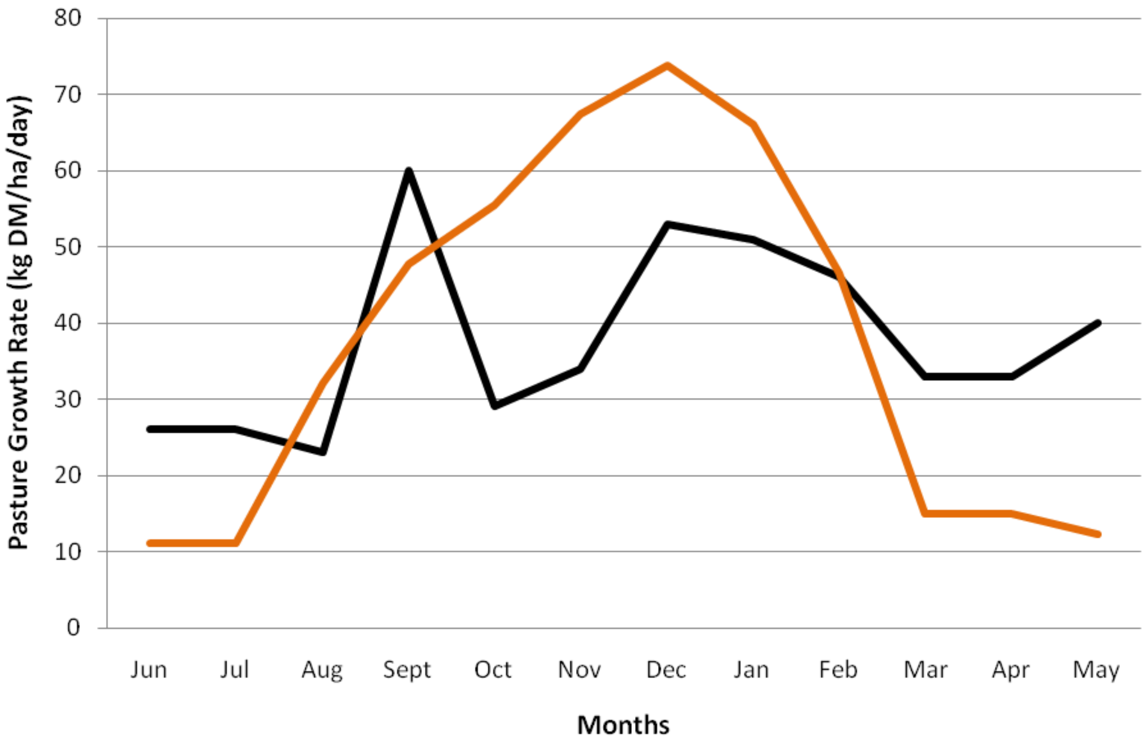


Figure 1 Pasture growth rates for base model (▬) and plus chicory model (▬).

Significant differences were observed between winter and summer growth rates for the Base and Plus Chicory model. The paddock including chicory in the sward grew slightly more (0.3% increase), but growth rates were proportionately scaled so that both the base and plus chicory models had the same total pasture grown. The basis behind this was to identify the benefits of inclusion of chicory alone, rather than a combined effect of more and higher quality pasture.

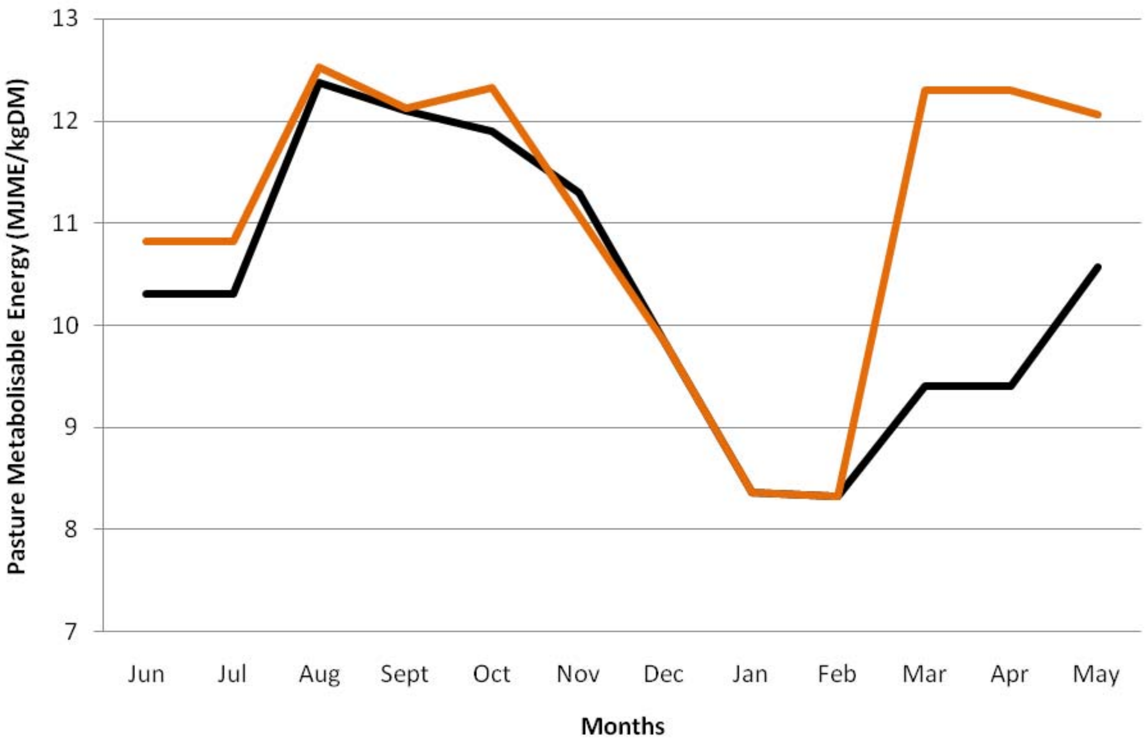


Figure 2 Pasture metabolisable energy values for base model (▬) and plus chicory model (▬).

Metabolisable energy for the two models were fairly similar until late summer/autumn, where the ME value of the Plus Chicory system was significantly higher than the Base model. It is over the summer/autumn months that the chicory is most actively growing and presents the benefit of high ME values when pasture ME can be less than adequate to meet animal demand.

The general expenses were based on forecast 2009/10 prices for the Waikato region and were expressed on a per ha or per cow basis, or calculated from the Farmax model where appropriate (Appendix A). The milk payout schedule for the 2008/09 season was used.

2.2 Model Outputs

Production

There are a number of different methods with which a farmer may manage chicory on their farm. For this modelling, total milksolids production per cow and average pasture cover for the whole season were kept relatively similar. This resulted in the major difference between the two models being the amount of supplementary feed being offered. The lactation curve and average pasture cover for the year are displayed in Figures 3 & 4 respectively.

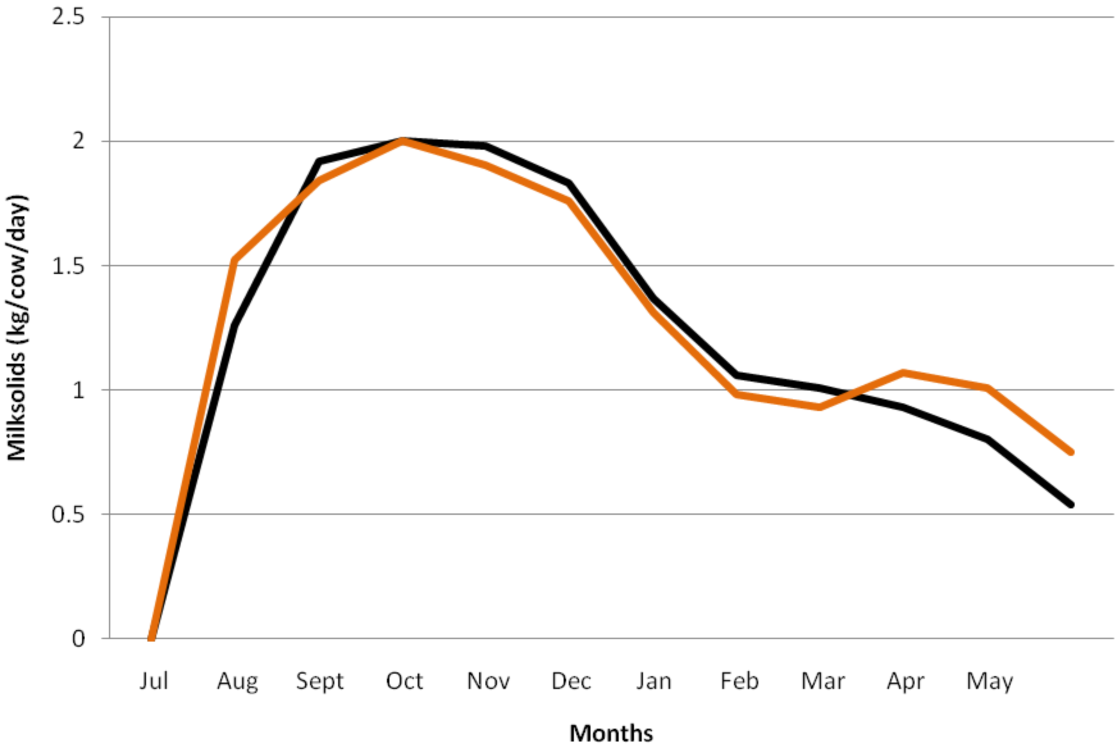


Figure 3 Lactation curve (kg MS/cow/day) for base model ( ) and plus chicory model ( ).

The lactation curves for the two models are very similar as the cows are producing the same amount of milksolids in the two models. With the higher ME of the available pasture in autumn the cows in the Plus Chicory model are able to produce more milksolids at a time where production is generally tapering off. The cows in the Plus Chicory model are achieving the same level of milksolids production with less feed, and therefore have a higher feed conversion efficiency.

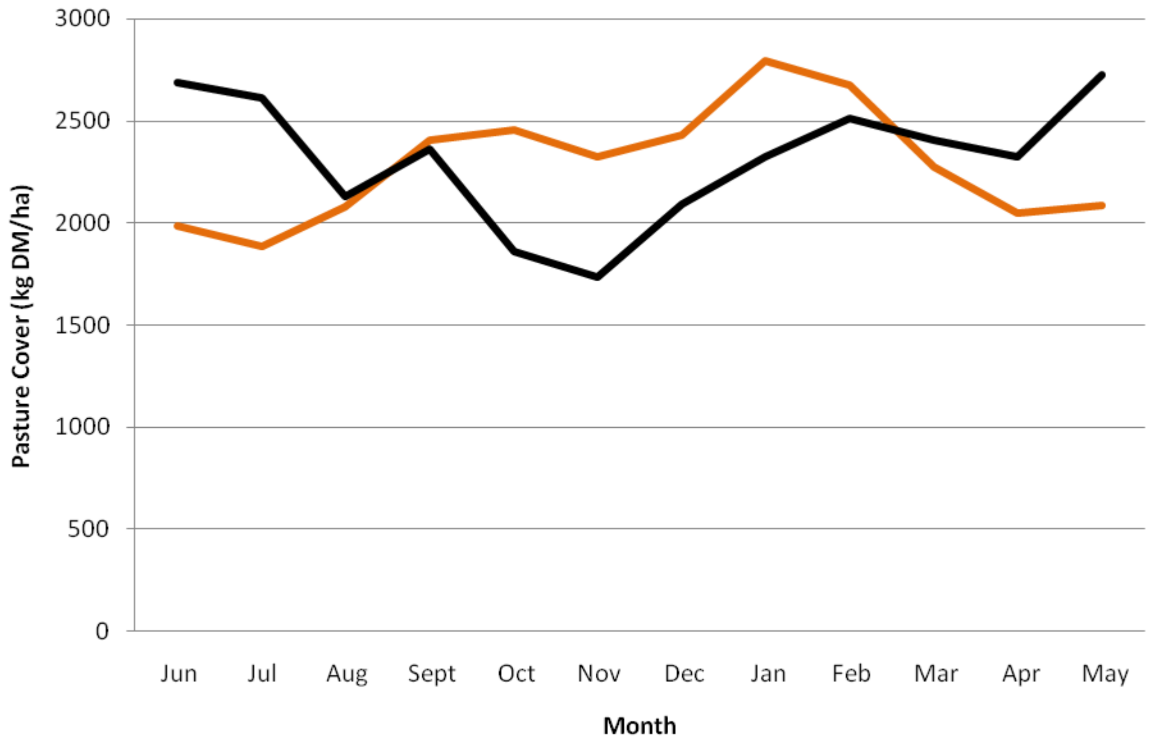


Figure 4 Average pasture cover (kg DM/ha) for the Base model (▬) and Plus Chicory model (▬).

While the average pasture cover for the two models look quite different, average pasture growth is similar for the whole season (Figure 4). The Base model pasture cover starts & ends the season with a much higher cover than the Plus Chicory model. This results in the Plus Chicory model being more reliant on supplementary feeds to meet animal demand over the dry period (i.e., when cows are not lactating), whereas the lower growth rate in summer for the Base model results in this system being more reliant on supplementary feeds during this period to keep the cows milking. From March onwards the Plus Chicory growth rates are below the Base model, and to ensure the pasture cover is adequate for the dry period intake of pasture needs to be managed with provision of supplementary feed.

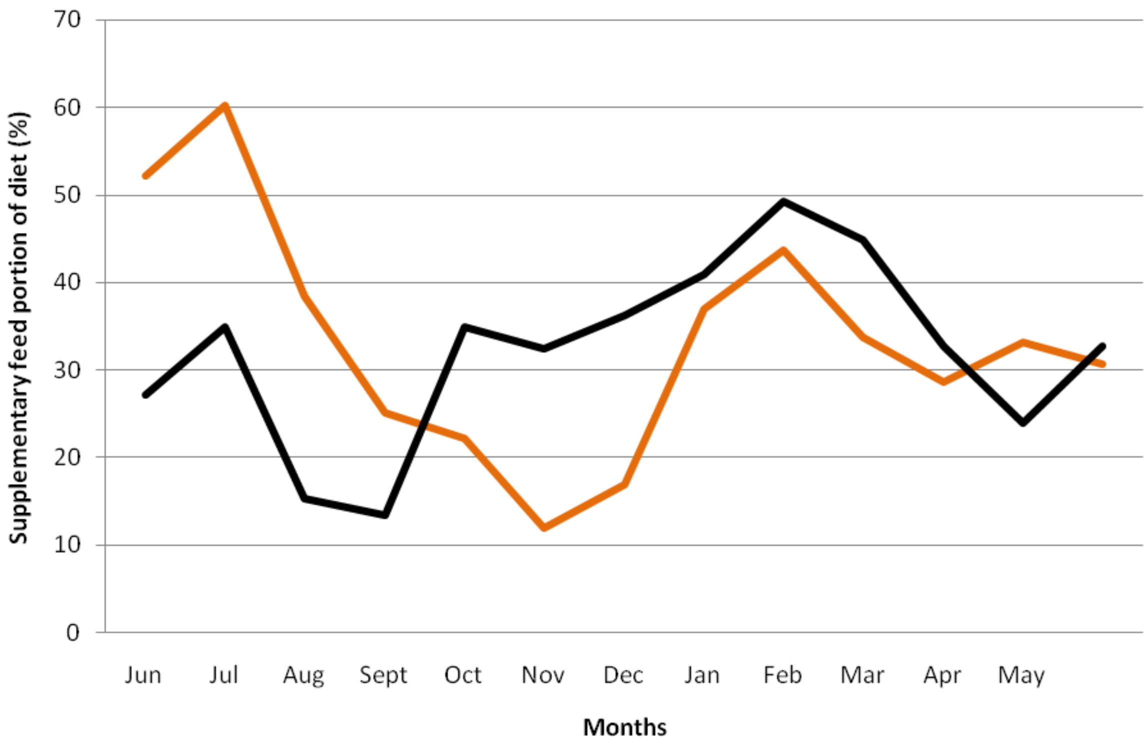


Figure 5 Supplementary feed use (% of diet) for the Base model (▬) and Plus Chicory model (▬).

As a result of variations in pasture growth rates (Figure 1) and metabolisable energy (Figure 2) both systems feed supplementary feed out all year (Figure 5). In the Base model imported supplementary feed is fed out for the majority of the year, in addition to conserved pasture silage being fed out during the dry period and summer grown turnips being fed in late summer/autumn. This supplementary feed is required to meet animal demand due to lack of pasture growth and low quality pasture. In the Plus Chicory system pasture growth rates over the dry period are reduced, which creates the need for further supplementation during the dry period with imported maize silage. The higher growth rates over summer in the Plus Chicory system reduce the need for supplementation, and in autumn the higher ME compensates for the reduction in growth further reducing the need for supplementation.

In response to the additional ME supplied by chicory, an alternative to reducing the use of supplementary feed could be to aim for higher milksolids per cow, or carrying more cows. Increasing per cow production is certainly more desirable, improving feed conversion efficiency, as the low winter growth rates already require significant supplementary feed substitution which would be exacerbated with more cows.

The primary changes to the Plus Chicory model were variation in pasture growth rates and ME. It is difficult to model and therefore not taken into account that chicory has a high digestibility and is digested in the rumen significantly faster than ryegrass, allowing for greater intakes.

Profitability

Table 2 provides the profitability for Base and Plus Chicory models. The Plus Chicory model was found to increase operating profit per hectare by $161. This increase in operating profit is due to the reduction in imported supplement (palm kernel). The high quality feed available during autumn and the subsequent drop in requirement for high energy supplementation in the Plus Chicory model reduces the reliance on imported supplementary feed and the associated risks of variation in feed prices and availability. This saving may be more marked in a dry summer/autumn when chicory is still able to grow, when its large tap root can source water from deeper in the soil profile, and supplementary feed prices rise due to the high demand.

Table 2 Profitability of the Base and Plus Chicory models.

	Base Model	***Plus Chicory***
Revenue		
Net Milk Sales	585421	583596
Net Livestock Sales	39087	37685
Change in Livestock Value	0	0
Gross Farm Revenue	624508	621281
Expenses		
Wages	102060	102060
Stock Expenses	53550	53550
Supplementary Feed	109056	89786
Grazing & Run-Off	67525	67525
Other Farm Working Expenses	102970	102970
Overheads	30800	30800
Depreciation	36000	36000
Total Operating Expenses	508260	488990
Operating Profit	116248	132291
Operating Profit per hectare	1162	1323

With a reduction in the use of supplementary feeds there may also be a drop in labour requirements, which could flow on to a reduction in labour costs. Public perception of some imported supplementary feeds (particularly palm kernel) generates some uncertainty to the future use of these products in New Zealand dairying systems. Alternatives to such products, like chicory, may become more popular as a source of high energy feed.

If the decision had been made to increase milk-solids production per cow or carry more cows then there would have been an increase in revenue from milk sales. More cows may have increased the requirement for supplementary feed over the winter period and would also generate more stock associated costs, both of which would increase overall farm expenses.

No adjustment was been made for the cost of the chicory seed. Sowing costs were assumed to be the same for both models. At the low rates of inclusion into a mixed pasture sward, and the multiple year benefits the cost of the seed is not expected to have a large effect on the increase in operating profit.

Other Considerations

Incorporating a proportion of the farm into either a mixed grass/clover/chicory sward or a pure chicory sward could have a number of potential benefits for all levels of dairy systems. There may be added advantages where chicory is used in lower level systems where no or very low levels of supplementation are used.

The greatest benefit from including chicory in the pasture sward is from the increase in growth over the summer period and the higher ME of the pasture, particularly in the late summer/autumn period. This benefit is likely to be even more marked during a summer dry season when chicory can sustain growth much longer than grass. The increased growth and ME of the pasture allows cow numbers to be maintained whilst milking on further into autumn, or reduce the use of any imported supplements. With the higher energy cows are able to potentially produce more or milk longer into the autumn, and could finish in better condition, reducing the need for large weight gain over the dry period.

Another option for the use of chicory is to have a pure sward. This can be break fed like a turnip crop, and observations have suggested that this crop will regenerate after grazing and last for 2-3 years. Again with minimal growth rates this crop is not suitable where winter feed is required. Stock should be back-fenced when grazing to minimise damage to growing points.

In either the case of a mixed pasture or pure sward of chicory it would be suited to do on a small proportion of the farm. Low growth rates over winter will require additional supplementation to meet animal demand, and if a large area was planted with chicory there may be a limitation to winter carrying capacity.

Grazing management of pure chicory swards or mixed pasture swards including chicory may need to be adjusted. Hard grazing, particularly during winter, can damage the growing points which will result in thinning out of the chicory. Observations have identified that over time the proportion of chicory in the sward will decline. Potential methods to increase the proportion of chicory in the sward are to allow the chicory to flower, re-seeding the paddock, or over-sowing with chicory seed. Dispersing seed within a paddock is best done in spring, prior to grazing, providing the best conditions for chicory growth.

When deciding to plant a pure sward of chicory or incorporate chicory into a pasture mix, weed eradication is particularly important. Many herbicides that are targeted for use on broad-leaved weed species and herbicides for thistles will also affect chicory. Therefore, it is important that these weeds are controlled prior to planting chicory, or alternative methods of control are used, like mowing for thistles.

3. Conclusion

Inclusion of chicory into a mixed pasture sward will affect pasture growth and ME. These factors may affect supplementary feed use (amount and timing), milk solids production (total and shape of lactation curve), seasonal pasture cover and profitability. The modelling showed the inclusion of chicory would increase operating profitability by $161/ha. There are many factors to consider when using chicory, with important consideration to be taken in the establishment phase and the grazing management of chicory.

Appendix 1

Expense inputs, calculated on a per hectare basis (unless stated).

	Cost ($/ha)
Wages	169 *(per cow)*
Management Wage	155 *(per cow)*
Total Labour	324 *(per cow)*
Animal Health	76 *(per cow)*
Breeding	40 *(per cow)*
Farm Dairy	20 *(per cow)*
Electricity	34 *(per cow)*
Total Stock	170 *(per cow)*
Conservation	Modelled
Cash Crops	Modelled
Forage Crops	Modelled
Purchased Feeds	Modelled
Calf Feeds	Modelled
Total Feed	-
Grazing	Modelled
Run-Off Lease	38
Owned Run-Off Adjustment	114
Total Grazing & Run-Off	-
Fertiliser (Excl. N)	240
Nitrogen	Modelled
Irrigation	4
Regrassing	Modelled
Weed & Pest	32
Vehicles	96
Fuel	100
R&M Land & Buildings	100
R&M Plant & Equipment	133
Freight	20 *(per cow)*
Total Other Farm Working	-
Administration	126
Insurance	42
ACC	42
Rates	98
Total Overheads	308
Depreciation	360

9. APPENDIX 2: 17 Australasian Weeds Conference submitted paper

New Zealand dryland pastures: effects of sown pasture species diversity on the ingress of unsown species

Katherine N. Tozer[1], Gary M. Barker[2], Catherine A. Cameron[1] and Nadine Loick[3]
[1] AgResearch, Ruakura Research Centre, East Street, Private Bag 3123, Hamilton 3240 and [3] Lincoln Research Centre Private Bag 4749, Christchurch, 8140, New Zealand
[2] Landcare Research, Private Bag 3127, Hamilton 3240, New Zealand

Summary Botanical composition was assessed in spring in 30 paddocks in each of four New Zealand regions: Northland (beef, sheep), Waikato (dairy), Taranki (dairy) and North Canterbury (beef, sheep, deer). Paddocks selected ranged in age and diversity of the sown mix (grasses + legumes, or grass + legumes + herbs). In all regions except for Taranaki, sown species declined and unsown species increased over time. This was mainly due to an increase in unsown grasses, although unsown herbs also increased. There was little unsown legume. In Northland, unsown herb ingress was less where herbs were sown, but only in older pastures. Total unsown cover in 4-6 year old pastures was: 41% (Waikato), 15% (Taranaki) and 25% (North Canterbury), while in 5-6 year old Northland pastures it was 25%. Most unsown species were undesirable. However, productive unsown species were also present (e.g. ryegrass, commercial plantain, white clover, subterranean clover).
Keywords species diversity, functional diversity, pasture persistence, weed ingress.

INTRODUCTION

Pasture persistence has been identified as a key issue in dairy, beef and sheep industries. Lack of persistence of sown species and ingress of weedy species can lead to significant production loss (Bourdôt *et al.* 2007). In addition, renovation costs are high. For example, it has been estimated that full renovation of a dairy paddock is well in excess of \$1000 ha^{-1}, taking into account all costs (Bay of Plenty dairy farmer, personal communication).

It has been demonstrated that increasing diversity of plant species in grassland communities can increase pasture resilience and resistance to invasion by exotic species (Sanderson *et al.* 2004). Often, it is the species identity that is most important, rather than the number of species *per se* (Crawley *et al.* 1999). This is related to their functional complementarity, or ability to respond to environmental factors in different ways to other species in the mix. Plants can therefore be classified according to their functional traits (e.g. perennial temperate grasses, perennial legumes, etc). In a New Zealand North Island hill country field study, it was shown that increasing the number of sown functional groups reduced the number of unsown species (Dodd *et al.* 2004).

In New Zealand, given that most pastures comprise perennial grasses and perennial legumes, a key means of increasing functional diversity is through sowing the herbaceous species chicory (*Cichorium intybus* L.) and plantain (*Plantago lanceolata* L.), which are drought tolerant and provide useful summer feed.

The hypothesis we tested was: can increasing functional diversity of sown species reduce ingress of unsown species as pastures age? Controlled studies to test the hypothesis would eliminate huge impacts of variation in management (e.g. beef and sheep versus dairy) and localized differences in climate that occur on different farms. Yet, we also needed to determine if there is evidence for this hypothesis in real-life farming situations and if there are consistent, documentable benefits. We therefore undertook an on-farm study in different regions throughout New Zealand to investigate the relationships between sown functional diversity, pasture age and ingress of unsown species.

MATERIALS AND METHODS

Sites Thirty paddocks were selected in Northland (sheep, beef), Waikato (dairy), Taranaki (dairy) and North Canterbury (sheep, beef, deer). These regions varied in climate, from Northland with mild winters and warm, subtropical summers which favour C4 summer-active species, to North Canterbury which has a much harsher climate of hot dry summers and cold winters. Paddocks were selected such that they ranged in age since renovation and in functional diversity of the sown mix (grasses + legumes vs. grasses + legumes + herbs). In addition, paddocks were only selected if: 1) farmers possessed good paddock history records (i.e., species, and cultivars sown, rates, seed coating, endophyte status, sowing date and method); 2) they were not irrigated (other than effluent spreading on a small number of dairy paddocks); and 3) no under or oversowing had occurred since renovation. Paddock sizes varied considerably, although most dairy paddocks were approximately 1.5 ha and most beef and sheep paddocks were several hectares in size. Two to three paddocks were randomly selected on each farm, equating to 10-15 farms in each region.

Sampling Assessments took up to one week in each region and were undertaken during spring 2009. In each paddock, botanical assessments were undertaken in a 1 hectare area. Percent cover of species present was assessed in 4, randomly placed 2 x 2 m quadrats.

Percentage of total dry matter was assessed in 20 0.1 m^2 quadrats in each paddock, using the BOTANAL method (Jones and Hargreaves 1979). This method visually ranks the 3 most dominant vegetation classes present in a quadrat, with respect to their dry matter contribution. Standard multipliers are then used to estimate the contribution of these vegetation classes to total pasture dry matter. Assessments were undertaken for sown and unsown grasses, legumes and herbs. Sown grasses included: ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), cocksfoot (*Dactylis glomerata* L.), prairie grass and grazing bromes (*Bromus* spp.), timothy (*Phleum pretense* L.) and phalaris (*Phalaris aquatic* L.), sown legumes included white clover (*Trifolium repens* L.), red clover (*T. pretense* L.), subterranean clover (*Trifolium subterraneum* L.), lucerne (*Medicago sativa* L.) and lotus (*Lotus* spp.), while sown herbs included chicory and plantain.

Statistical design There were two treatments: functional diversity and age. Of the 30 paddocks in each region, 15 paddocks were selected in which grasses and legumes had been sown (2 functional groups), and 15 paddocks in which grasses, legumes and herbs had been sown (3 functional groups). In each region, the 15 paddocks in each category were further subdivided into 'young' (renovated in the last 1-3 years), medium (4-6 years) and 'old' (7 years or more). However, in Northland, it was not possible to locate sufficient renovated paddocks with good paddock histories that were over 6 years old. Therefore, young was defined as 1-2 years, medium as 3-4 years and old as 5-6 years. This gave approximately 5 paddocks for each age and diversity category within each region.

REML was undertaken using GenStat 10.2 (VSN International Ltd., Oxford), with farm as a random effect, on the proportion of total dry matter and percent cover of the different vegetation classes present, including total sown and unsown species, and sown and unsown grasses, legumes and herbs.

RESULTS

Northland sheep and beef: Total sown species content was greater in young than old pastures (90, 77 and 69% of total dry matter in young, medium and old pastures respectively). There was no difference between treatments in cover, although the trend was similar (Table 1).

Sown grass content was higher in young and medium aged pastures, when sown without than with herbs, but was similar in old pastures (young pastures: 81% and 57% of total dry matter, medium pastures: 71% and 46%, old pastures: 53% and 57%, without and with sown herbs respectively, $P < 0.05$). This was due to a decline in sown grass content as pastures aged, when sown without herbs.

Content of unsown species was greater in medium and old than in young pastures ($P < 0.05$). Similar trends were observed for cover, although they were not significant (Table 2). This was primarily due to an increase in unsown herbs, which contributed more dry matter in the old (11%) than young pastures (2%, $P < 0.01$). In addition, ingress of unsown herbs (e.g., buttercup (*Rananculus* spp.), dock (*Rumex* spp.), penny-royal (*Mentha pulegium* L.)) was less (5%) in pasture sown with than without (17%) herbs, but only in old pastures ($P < 0.05$, % of total dry matter). Unsown grass content was not affected by age or by sowing herbs (6, 17 and 18% of total dry matter respectively, in young, medium and old pastures). Unsown legumes contributed little dry matter and pasture cover (Table 2).

Table 1. Mean percent cover of all sown species (grasses, legumes and herbs) in 'young', 'medium' and 'old' dryland pastures. Means with different subscripts are significantly different ($P = 0.05$).

Region	Young	Medium	Old	SED
Northland	84	68	69	7.2
Waikato	75_a	59	55_b	8.5
Taranaki	85	81	86	3.5
Canterbury	78	74	60	9.1

Waikato dairy: Sown species cover was greater in young (75%) than old pastures (55%, Table 1).

Conversely, cover of unsown species was higher in medium and old (both 41%) than in young pastures (15%, Table 2, $P = 0.05$). This was due primarily to the change in cover of unsown grasses, which were much higher in medium (27%) and old (28%) than in young (6%) pastures ($P =$

0.01). However, there was no change in the cover of unsown herbs, which remained below 14%. There were negligible unsown legumes.

Table 2. Mean percent cover of unsown species in 'young', 'medium' and 'old' dryland pastures for North Canterbury, Tarankai and Waikato. Means with different subscripts are significantly different (*P* = 0.05).

Vegetation	Young	Medium	Old	SED
Northland				
Grasses	9	23	14	7.0
Legumes	1	1	1	1.6
Herbs	4	6	9	2.3
Total	14	29	25	7.5
Waikato				
Grasses	6_a	27_b	28_b	8.5
Legumes	0	0	0	
Herbs	9	14	12	3.4
Total	15_a	41_b	41_b	8.6
Taranaki				
Grasses	2	3	2	1.1
Legumes	0	0	0	
Herbs	10	12	10	2.7
Total	12	15	12	3.0
Canterbury				
Grasses	7_a	13	23_b	5.9
Legumes	9	12	9	6.6
Herbs	1_a	1_a	3_b	1.0
Total	15_a	25	38_b	9.7

Taranaki dairy: Total sown species cover did not alter with pasture age (mean = 84%, Table 1).
There was no change in cover of unsown species as pastures aged; their total cover remained at 12-15% (Table 2). However, there was less (1%) bare ground in pastures sown with than without herbs (5%, *P* = 0.05).
North Canterbury sheep, beef and deer: The dry matter content (% of total dry matter) of sown species was greater in young (87%) and medium (85%) than in old (65%) pastures (*P* < 0.05). A similar trend was evident in % cover but did not reach statistical significance (Table 1).
Cover of unsown species was greater in old than young pastures (Table 2, *P* = 0.05). This was due to an increase in unsown grasses (7, 13 and 23% cover in young, medium and old pastures respectively, *P* < 0.05) and unsown herbs (1, 1 and 3% cover in young, medium and old pastures respectively, *P* < 0.05). There was less bare ground (3%) in pastures sown with than without (12%) herbs, but only when pastures were young (*P* < 0.05).

DISCUSSION

A reduction in sown species and increase in unsown species was evident in all regions as pastures aged, except in Taranaki. Most pastures assessed in this study were less than 10 years old, and in Northland, all were less than 6 years old. Yet in Waikato, unsown species cover had reached 40% within 4 years of sowing and 25% in North Canterbury.
There was evidence that increasing species diversity improved persistence of sown species in Northland, thus reducing the ingress of unsown species. This concurs with other studies, in which increasing functional diversity increases resilience (Dodd *et al.* 2004). This also concurs with anecdotal evidence provided by farmers interviewed for this project. A number of the farmers observed that sowing a combination of species that were adapted to a range of environmental conditions (e.g. winter-active species such as ryegrass or bromes and summer-active or more drought tolerant species such as lucerne or cocksfoot) improved pasture persistence and lessened the ingress of undesirable species, (e.g., Californian thistle *Cirsium arvense* (L.) Scop.; barley grass *Hordeum murinum* L.). Overall however, we only detected weak relationships between sown functional diversity and unsown species ingress. It may be that the functional diversity was insufficient for effects to be detectable, especially as sown herbs comprised a small amount of the

pasture cover and content. Further, the classification we chose (grass + legumes vs. grasses + legumes + herbs) may be too simplistic to detect benefits of functional diversity. Further analyses are in progress.

While sown species composition can affect weed abundance, maintaining an even distribution of forage species is also important. In an American grazed field study, species evenness was negatively correlated to weed abundance over two consecutive years (Tracy *et al.* 2004).

The identity of unsown species in this study varied between regions, although winter grass (*Poa annua* L.) was prevalent in all regions. C4 grasses, such as kikuyu (*Pennisetum clandestinum* Hochst. Ex Chiov.) was detected in Northland, while temperate species such as browntop (*Agrostis capillaries* L.), barley grass and vulpia (*Vulpia* spp.) were more prevalent in Canterbury. Unsown species were often undesirable, as farmers viewed them as less productive, less palatable and of poorer forage quality, especially during seed maturation. In addition, seeds of some of the species observed can damage hides or carcasses of grazing livestock (e.g. vulpia, barley grass, storksbill (*Erodium* spp.) (Dowling *et al.* 2000).

In addition to weedy undesirable species, some unsown species were productive, such as ryegrass, subterranean clover or commercial cultivars of plantain. Ryegrass was documented in many pastures where it was not sown, in varying amounts. For example, ryegrass was the dominant species present (> 50% of total dry matter) in one 4 year old Waikato paddock, which was sown with tall fescue and established well in its first year. Therefore, it is also likely that old varieties of ryegrass were present in pastures where newer cultivars of ryegrass were sown (Burggraaf and Thom 2000). Ingress of older ryegrass cultivars would result in an overestimation of sown grasses and underestimation of unsown grasses, as it was not possible in the field to identify different ryegrass cultivars. Further work is underway to test for endophyte identity of the ryegrass present, which will enable us to determine how well the sown ryegrass cultivars are persisting.

Commercial cultivars of plantain were likewise found in small quantities where it had not been sown. This occurred in all regions assessed. Farmers observed that plantain appeared to self-seed readily and to establish in stock dung. Plantain was usually present in ‘old’ pastures in which it was sown, in contrast to chicory, which appeared to be less persistent. Plantain may show more promise than chicory in preventing the ingress of unsown species.

Ingress of unsown species and persistence of sown species varied between regions; further analyses are underway to quantify these differences. Variation may reflect differences in climate, as well as in enterprise (sheep vs. dairy etc). For example, Taranaki tended to have the highest proportion of sown species in the pastures, while Waikato, Northland and North Canterbury had greater ingress of unsown species. In Taranaki, average maximum temperature (17^{o}C) and rainfall (1604 mm) in years in which pastures were sown would favour establishment of ryegrass, the dominant sown grass. In comparison, mean Canterbury rainfall in the years in which pastures were sown was much lower (789 mm). Also, there were numerous summer droughts over the last decade in Canterbury, which would reduce vigour of sown species and favour winter-active annual grasses, such as vulpia, winter grass and barley grass, which avoid the summer drought. These differences between regions give insights into how pastures may perform as regional climates change.

While there is only limited evidence for the hypothesis that increasing functional diversity (by including herbs) reduces ingress of unsown species, results give us valuable insight into persistence of sown species and ingress of unsown species. Currently, a study is underway to further test this hypothesis relating to functional diversity, under controlled conditions, in replicated field plots. In combination with results from the present study, we can better ascertain the role and potential benefits of functional diversity on pasture persistence and weed ingress in New Zealand pastures.

ACKNOWLEDGMENTS

Many thanks to farmers and industry personnel who kindly gave of their time. Thanks also to MAF (SLMACC, SFF), DairyNZ**,** Environment Waikato and Environment Bay of Plenty for funding this project. Derrick Wilson, Mike Trolove, Shona Lamoureaux and Yuki Fukuda gave invaluable assistance with collection of field data.

REFERENCES

Bourdôt GW, Fowler SV, Edwards GR, Kriticos DJ, Kean JM, Rahman A, Parsons AJ (2007) Pastoral weeds in New Zealand: status and potential solutions. *New Zealand Journal of Agricultural Research* **50**, 139-161.

Burggraaf VT, Thom ER (2000) Contamination and persistence of endophyte-free ryegrass pastures established by spray-drilling, and intensively grazed by dairy cows in the Waikato region of New Zealand. *New Zealand Journal of Agricultural Research* **43**, 163-173.

Crawley MJ, Brown SL, Heard MS, Edwards GR (1999) Invasion-resistance in experimental grassland communities: species richness or species identity? *Ecology Letters* **2**, 140-148.

Dodd MB, Barker DJ, Wedderburn ME (2004) Plant diversity effects on herbage production and compositional changes in New Zealand hill country pastures. *Grass and Forage Science* **59**, 29-40.
Dowling PM, Michalk DL, Sindel BM (2000) Weed management in pasture systems. In 'Australian weed management systems'. (Ed. BM Sindel) pp. 306-328. (R.G. and F.J. Richardson: Meredith, Victoria, Australia).
Jones RM, Hargreaves JNG (1979) Improvements to the dry-weight-rank method for measuring botanical composition *Grass and Forage Science* **34**, 181-189.
Sanderson MA, Skinner RH, Barker DJ, Edwards GR, Tracy BF, Wedin DA (2004) Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Science* **44**, 1132-1144.
Tracy BF, Renne IJ, Gerrish J, Sanderson MA (2004) Effects of plant diversity on invasion of weed species in experimental pasture communities. *Basic and Applied Ecology* **5**, 543-550.