The challenges facing legumes in a dryland environment - a consultant's view

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Abstract

The dryland regions of New Zealand suffer from summer moisture deficits in the majority of years. These dryland regions have been developed along the same basis as other farming regions, with increasing fertiliser usage leading to more subdivision and higher stocking rates. Given the exposure to droughts, the production per head of these regions has been extremely variable. Historically, dryland farming systems have been based around breeding ewe systems with all lambs finished if the season allowed. Since the removal of all Government support during adverse events, in the early 1990s, farm systems have become considerably more diverse. Irrigation areas have doubled between 1985 and 1999 to approximately 500 000 hectares. Both sub clover and lucerne have been used extensively in dryland areas, but the main legume is still white clover. Farmers recognise the significant limitations in the ability of white clovers to cope with summer droughts, but have not been able to efficiently utilise other legumes, which require unique management to perform. There are a number of reasons for this. Looking forward, the five key roles that legumes have in dryland farming systems are, to persist within a general purpose pasture, to produce nitrogen, to improve summer feed quality, to improve year round quality feed through specialist crops and pastures and to provide specialist composite feeds (i.e. condensed tannins). With the increased diversity in farming systems, growers require a more diverse range of legumes from perennial species to annuals that will fit a short-term high feed quality niche.

Introduction

The dryland farming regions of New Zealand make up a significant area of the east coast stretching from Hawke's Bay in the North Island down to East Otago in the South Island. There are also other pockets of dryland regions in inland areas of Central Otago and South Canterbury. Dryland farming regions are generally defined within the farming community as those environments where summer evapotranspiration exceeds summer rainfall in the majority of years. A total of 2 872 295 hectares of land received 800mm of annual rainfall or less between the period 1950-1980 (Table 1). This is 10.7% of the total New Zealand land area.

Within the dryland areas there are both extensive, semi-intensive and intensively farmed areas. The extensively farmed environments are generally in the South Island hill and high country and are based around adult beef cattle and merino-based sheep breeds. This paper focuses more on the intensive and semi intensive areas with less than 15 degrees slope.

History

These dryland areas were among the earliest to be settled and farmed in New Zealand, because their flat rangeland nature was well suited to extensive pastoral systems. They were also well suited to cereal cropping, which naturally led to increased intensification and development through sowing of "English grasses". The soldier resettlements following both World Wars also added further development

Table 1 Total hectares of New Zealand with 800 mm annual rainfall and less (1950–1980).

	Total area (ha)	<800 mm annual rainfall all land classes	% of Total
South Island	15 310 227	2 855 989	18.65
North Island	11 443 537	16 306	0.14
Total	26 753 766	2 872 295	10.7

(Source: Agribase data 2003, MAF Policy)

impetus. With tractors replacing horses in the 1950s, typical farming systems involved 5–10 year pasture renewal rotations through brassicas, cereal straw crops, and ryegrasses. The inability of white clover to cope with summer drought was already well recognised, and sub-clover was often the most important legume component. Ryegrass varieties were limited to ‘Ruanui’ and ‘Pae-roa.’ The release of ‘Tama’ in the 1970s was a major technology advance at that time. Soil pH levels were typically only 5.4, and phosphate levels were 6 - little wonder clover struggled to survive. The 1970s saw increased use of fertiliser, lime, and subdivision, and considerable use of lucerne as an option to “drought-proof” farms. Subsidy and incentive schemes designed to boost pastoral production (e.g. \$1 per sheep in the budget of 1975, and land development encouragement loans), combined with central government assistance in times of drought, meant farms were basically overstocked and per head productivity remained static for 30 years (Brown 1996).

By the mid 1980s the use of lucerne had all but disappeared, due to the main variety’s (‘Wairau’) susceptibility to pests and disease. The introduction of crossbred sheep breeds over this period, resulting from a crash in wool prices, led to a significant increase in meat output. Soil fertility levels continued to improve slowly, although the recommended Olsen P levels of 12 (according to the MAF fertility model) were low by current standards. Stocking rates had lifted to record levels of 10 stock units per hectare, but per head production was very dependent on rainfall.

In the mid 1980s, a change in government economic policy and removal of the support mechanisms for agriculture saw profitability plummet as farmers struggled to survive. This period, combined with severe droughts in 1985 and 1988 saw some negative media publicity focus on farmer management of stock and land (e.g. dust storms). The concept of environmental sustainability started to gain prominence. Many agriculture advisers of the time were involved in the first serious attempt to encourage farmers to use direct drilling and other technologies to establish non-ryegrass based pastures through much of the east coast. At the risk of being accused of generalising, up until this point, ryegrass and ‘Huia’ white clover was the pasture mix of choice, from dairy farms in Northland to deer farms in Southland and everything in between!

The 1990s saw a return to higher farming returns (Table 2) and productivity (Table 3) through improved animal genetics and pasture cultivars. Wide ranges of pasture species and cultivar options became available, also improved market signals and variety of product options. Irrigation was also becoming very important in changing the face of pastoral agriculture, with a 100% increase in irrigated area from the mid 1980s (Figure 1) and a trend in land use away from pastoral agriculture (Figure 2).

Figure 1 Irrigation areas in New Zealand.

(Source: Information on water allocation in New Zealand. Report No 4375/1, April 2002, MfE.)

1965 Irrigated Area - MAF Survey

1997 Irrigated Area - LE Survey

Figure 2 Trends in irrigation area by land use.

(Source: Information on water allocation in New Zealand. Report No 4375/1, April 2002, MfE.)

Table 2 Summary of South Island finishing/breeding data from 1980-2003.
Class 6 – MWI Economic Service

Year	Wool account total	Sheep account total	Cattle account total	Total gross revenue	Total farm expenditure	Farm profit before tax	Current value as a going concern at close \$/ha
1980-81	\$33 451	\$31 976	\$9 519	\$81 696	\$63 192	\$18 504	\$1 985
1981-82	\$41 472	\$36 408	\$9 409	\$93 112	\$77 229	\$15 883	\$2 297
1982-83	\$38 619	\$38 379	\$8 092	\$95 024	\$81 566	\$13 458	\$2 149
1983-84	\$39 983	\$40 783	\$6 519	\$99 406	\$83 742	\$15 664	\$2 333
1984-85	\$48 577	\$51 338	\$9 680	\$124 712	\$96 020	\$28 692	\$1 987
1985-86	\$42 440	\$28 053	\$7 122	\$94 839	\$83 541	\$22 298	\$1 480
1986-87	\$51 912	\$38 955	\$10 349	\$115 157	\$86 683	\$28 474	\$1 570
1987-88	\$58 956	\$39 580	\$11 551	\$121 412	\$97 891	\$23 521	\$1 481
1988-89	\$55 978	\$24 581	\$8 896	\$99 522	\$91 362	\$8 160	\$1 602
1989-90	\$53 970	\$48 328	\$16 060	\$134 243	\$98 681	\$35 562	\$2 011
1990-91	\$38 828	\$50 001	\$17 107	\$120 529	\$99 372	\$21 157	\$2 070
1991-92	\$42 120	\$50 251	\$18 793	\$127 193	\$100 970	\$26 223	\$2 263
1992-93	\$36 122	\$58 914	\$20 926	\$133 605	\$114 886	\$18 719	\$2 768
1993-94	\$34 863	\$81 779	\$23 723	\$158 426	\$113 833	\$44 593	\$3 412
1994-95	\$52 980	\$72 288	\$22 111	\$164 100	\$123 999	\$40 101	\$3 182
1995-96	\$47 675	\$71 471	\$18 973	\$161 729	\$136 883	\$24 846	\$3 080
1996-97	\$46 411	\$110 000	\$20 005	\$202 035	\$151 057	\$50 978	\$3 240
1997-98	\$44 685	\$101 259	\$21 317	\$192 144	\$157 036	\$35 108	\$3 135
1998-99	\$40 673	\$95 618	\$19 163	\$176 445	\$150 688	\$25 757	\$3 168
1999-00	\$42 160	\$120 783	\$35 518	\$222 801	\$164 318	\$58 483	\$3 548
2000-01	\$52 593	\$165 501	\$45 765	\$292 601	\$199 244	\$93 357	\$4 531
2001-02	\$49 300	\$184 000	\$51 900	\$312 400	\$189 741	\$122 659	
2002-03	\$52 200	\$177 000	\$37 300	\$292 300	\$182 520	\$109 780	

Table 3 Summary of South Island finishing/breeding data from 1980-2003
Class 6 – MWI Economic Service

Year	Lambing %	Total effective area (ha)	WoolPro per sheep wt (kg)	Stock units per (S.U.) ha	Sheep S.U. at open	Cattle S.U. at open	Deer S.U. at open	Goat S.U. at open	Total S.U. at open
1980-81	112.7	355	4.84	9.1	2 801	432			3 233
1981-82	104.3	356	4.42	9.2	2 879	382			3 261
1982-83	100.1	353	4.13	9.0	2 913	277			3 190
1983-84	102.4	345	4.40	9.0	2 826	265	4	5	3 100
1984-85	113.1	345	4.64	9.2	2 869	277	9	8	3 163
1985-86	103.8	353	4.55	8.8	2 796	292	6	14	3 108
1986-87	105.2	352	4.59	9.2	2 878	335	5	17	3 235
1987-88	111.0	360	4.79	8.9	2 830	370	8	13	3 221
1988-89	101.7	358	4.05	9.0	2 829	373	10	19	3 231
1989-90	101.4	364	4.52	8.2	2 601	326	19	22	2 968
1990-91	103.2	381	4.24	8.3	2 748	376	35	17	3 176
1991-92	105.4	386	4.48	8.3	2 772	398	28	9	3 207
1992-93	92.1	378	4.11	8.4	2 677	437	50	10	3 174
1993-94	108.0	366	4.70	8.3	2 544	449	37	8	3 038
1994-95	114.3	410	4.75	8.8	2 965	569	39	17	3 590
1995-96	102.4	425	4.39	8.8	3 073	632	49	5	3 759
1996-97	115.5	436	4.72	8.8	3 133	629	53	7	3 822
1997-98	118.8	439	4.59	9.0	3 186	680	59	7	3 932
1998-99	118.9	430	4.82	8.5	3 022	565	51	6	3 644
1999-00	118.3	448	4.67	8.6	3 120	653	67	5	3 845
2000-01	118.0	472	4.96	8.6	3 238	724	102	4	4 068
2001-02p	-	472	4.77	8.2	3 076	727	71	4	3 878
2002-03e	-	472	4.74	8.4	3 111	786	72	4	3 973

Notes: p = provisional e = estimate

Source: MWI Economic Service, Sheep and Beef Farm Survey

Consequently, farming systems are considerably more varied, because farmers have adopted systems that give the desired risk and reward trade-off for the land, water, and capital resources. However, white clover is still the legume of predominant use, primarily because it is relatively inexpensive, widely available, and well known. By comparison, alternative legume adoption has been limited by lack of industry and research support, the high cost of seed, lack of seed supply, and limited range of cultivar choices. The authors have estimated the approximate volumes of seed sold in NZ each year at 1 000-1 200 tonnes for white clover, compared with only 100-150 tonnes of red clover, 150-200 tonnes of lucerne, 40-60 tonnes of subterranean clover, and 30-50 tonnes for all other forage legumes combined.

The important point to take from this brief historical summary is that for 50 years post-World War II, base farming systems remained relatively unchanged. Over the past 10 years, there has been a revolution in both the technologies available and the farming systems employed. Thus, a challenge for farmers, policy makers, agribusiness owners and scientists, is to not apply yesterday's thinking to the role of legumes in future farming systems.

The roles legumes play in dryland farming systems

There are five distinct and definable roles for legumes to fill.

1. **Perennial workhorse:** Legumes which persist within a general-purpose perennial pasture and produce high quality feed when soil fertility and moisture allow. This has traditionally been the role of white and sub clovers.
2. **Nitrogen producers:** Legumes which serve as a nitrogen source, either within a short-term pasture or crop or within a perennial pasture. There is obvious economic impact is (\$210 M per year for the South Island dryland alone, Table 4), but with increasing regulatory and market demand for environmental sustainability, nitrogen production is also "eco-friendly". Nitrogen's importance to grass dry matter production and grass quality under a dryland environment is well known and documented.

3. **High quality summer feed source:** Legumes can improve summer feed quality within a grass mix when the quality of grasses has deteriorated. The superiority of legumes over grass for animal production in summer is well known (Table 5), resulting in greater productivity and feed conversion efficiency (Table 6).
4. **Contributors to year round feed quality:** Legumes can be used as a specialist crop to be grazed in situ or conserved as hay or silage. Both perennial crops (e.g. lucerne) and shorter term crops (e.g. 'Sulla') have roles within dryland systems to maximise meat production and dry matter production per hectare.
5. **Designer Feeds:** Legumes can serve as a component of "designer" or specialist composite feeds. Condensed tannins, that facilitate more efficient protein conversion, chemical compounds that achieve lower internal parasite burdens, and those that achieve a change in meat flavour are already conceivable, if not yet achievable.

Table 4 Estimated annual value of nitrogen fixed by clover-based pastures in dryland regions of the South Island (800 mm or less of annual rainfall).

Land class	Area in pastoral production ^a (M ha)	Estimated N ^b (kg N/ha/yr)	N fixation (Tonnes/yr)	Value ^c (million\$)
< 15° slope	1.406	185	260 10	338
> 15° slope	0.775	20	15 000	19
Total	2.181	126	275 610	357

^aSource: NIWA

^bSource: Hoglund *et al.* (1979)

^cSource: Applied Nitrogen costs estimated at \$1 300/tonne.

Table 5 Percentage protein, carbohydrate and comparative sheep live weight gain of ryegrass, white clover and lucerne.

	Crude protein (%)	Useable carbohydrate (%)	Structural carbohydrate (%)	Comparative live weight gain (g/hd/d)
Perennial ryegrass	16	12	30	100
White clover	25	20	17	192
Lucerne	18-20	15	25	157

Source: Ulyatt (1981)

Table 6 Total energy consumed rearing a lamb from 25 to 35 kg of live weight at various daily growth rates. (MJME: megajoules of metabolisable energy)

	Energy/lamb/day (MJME)	Days on farm	Energy consumed per lamb (MJME)
100 grams/day	13	100	1 300
200 grams/day	17	50	850
300 grams/day	22	33	726

Source: Brown (1990)

Factors in legumes favour

- Better understanding by farmers of their farming systems through monitoring. Growers are no longer looking for all their requirements to be delivered by a single cultivar. They understand and are adopting the technically advanced management systems often required by modern cultivars.
- Better soil fertility. P levels in excess of 20 are now commonplace.
- Better technology. Examples include drills, subdivision, computer decision aids, precision agriculture tools, novel grass endophytes that are more clover friendly and double spray techniques for moisture conservation.
- Better pasture management. Farmers are prepared to feed supplements or sell stock early to spell pastures to allow recovery when moisture arrives.
- Flexible systems. The variety of stock systems within a farm and the choices of companion grasses provide greater opportunity for a legume to receive the management it requires to perform well.

Challenges for legumes

- Competition from grasses. New ryegrass cultivars released to the market yielded 6% more herbage annually on average and 9% in summer, than cultivars available before 1991. (Easton *et al.* 2001)
- Competition from pests. While perennial pests such as slugs, nematodes and grass grub still cause significant damage, more recent arrivals such as clover root weevil will continue to be a problem.
- Competition from nitrogen fertiliser. With an increasing need to achieve maximum growth

during buoyant periods of adequate moisture, applied nitrogen will become an increasingly common practice.

- Time pressures. The need to optimise valuable land resources means a legume with a slow establishment phase is not very useful.
- Moisture availability. As water becomes a more scarce and expensive resource, it will only be directed where there is adequate productivity and financial payback. This may not be a legume, but a forage cereal, or other crops, resulting in the semi-irrigated legume becoming a true dryland site, or in legumes not being planted at all, due to their inability to perform in low or limited moisture situations.
- Persistence in drought. New cultivars must achieve better persistence and the capacity to survive periods of adversity, particularly the combination of drought and overgrazing.
- Lower temperature thresholds. In dryland environments, periods of adequate moisture frequently coincide with autumn, winter, and spring, when soil and air temperatures are hovering in the 5 to 8 °C range.

Conclusion

Legumes play a well documented, vital role in New Zealand pastoral agriculture, for the nitrogen they contribute, and the quantity and quality contribution they make to the grazing sward, and hence animal productivity.

There has been a major evolutionary change to dryland systems since the mid 1990s, with a renewed confidence in the productivity and opportunities in this class of land. Wide ranges of farming systems have developed to both improve profitability and reduce the exposure to dry summers. The complex nature of dryland farming systems has produced a wide variability in farmer's seasonal dry matter production and feed quality needs. There is an opportunity and a need to widen the range of legumes used, and moving away from the dominance of white clover and acquiring the knowledge and management skill that each of these specialist legumes require. If this can be achieved, there will be a further improvement in productivity, sustainability and profitability of dryland farming systems, and hence, New Zealand agriculture.

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