DERRICK MOOT

# OVERCOMING THE WEAKEST LINK IN PASTORAL FARMING – A LACK OF NITROGEN

**This article describes the global importance of nitrogen for agricultural systems and how nitrogen deficiency has been overcome to transform pastoral farming in New Zealand in the last 20 years.**

### Feeding the world with finite land

All plants are nitrogen (N) deficient all the time – except those that fix N. This simple fact has shaped the direction of agriculture since Neolithic man first planted crops and started nitrate leaching about eight million years ago. Today the need for N to drive food production is central to feeding 7.5 billion people on a finite land resource. *Figure 1* shows that the world production of the staple grains increased significantly during the 'green revolution' as inorganic N use increased in the middle of last century.

### Importance of N fertiliser

It is estimated that 50% of the people alive today owe their existence to the production and use of N fertiliser. The amount of inorganic N used in agricultural production continues to increase annually. Arguably the intensification of agriculture, enabled by the use of N fertiliser, has saved much of the natural world from destruction as more food is produced per unit of land area to meet the feed demand of the exponential increase in the human population.

If heeded, calls to limit the use of N fertiliser will inevitably lead to greater destruction of the natural world and human starvation. Similarly, meta-analyses show an average 20% yield reduction from organic food production systems. This means 20% more land would be required to produce the same amount of food if these systems were embraced globally. In short, N applied to land-based food production systems has fed the world's population and thus enabled the rapid rise in the standard of living, technological developments, the preservation of natural ecosystems, and led to the relative peace that exists today.

### Role of N in plants

For agricultural scientists the challenge is to provide N to meet plant needs as sustainably as possible. The role of N in plants is well known – it is an essential macro-nutrient that drives photosynthesis. The more N present, the darker the green because more chlorophyll is present per unit of leaf area. However, it is actually the increase in leaf area that N promotes which is the most important factor that leads to increased yields.

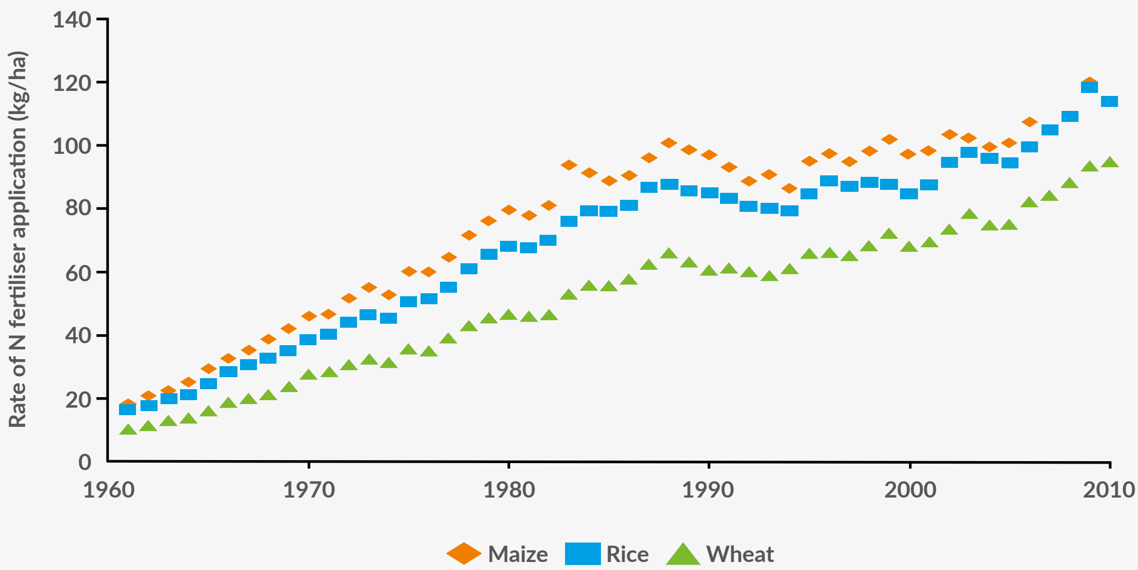


**Figure 1: Trends in global averages of N fertiliser application rates in maize, rice and wheat.**
*Source: Ladha et al., 2016*

*Lucerne in flower*

Leaf extension when a crop is first planted, or a pasture recovers after grazing, is the key to capturing all of the available light and therefore maximising the yield potential of any given environment. In practice we see the N response as taller darker leaves in a urine patch, or longer darker leaves in a wheat crop where N application encourages tiller survival and promotes grain quality.

### Effects on pasture yield

Before 1990 the use of N fertiliser in New Zealand agricultural systems was low, but we have seen a rapid increase in the application of fertiliser, particularly with the expansion of the dairy industry ***(Figure 2)***. This was inevitable as flat land, with high yield potential, was converted from dryland sheep production to dairy farming.

***Table 1*** shows those original dryland pastures produced about 6 t DM/ha, but when water was applied from irrigation the annual production increased to 10 t DM/ha/yr. It was only when N was added with irrigation that the environmental yield potential of over 20 t DM/ha/yr was achieved.

**Table 1: Total annual DM yield (t DM/ha/yr) of irrigated (I) or dryland (D) pastures grown with (+N) or without (-N) non-limiting N fertiliser at Lincoln University, Canterbury, NZ.**

| TREATMENT | ANNUAL YIELD (t DM/ha) |
|---|---|
| I+N | 21.9 |
| I-N | 9.8 |
| D+N | 15.8 |
| D-N | 6.0 |

*Source: Mills et al., 2009*

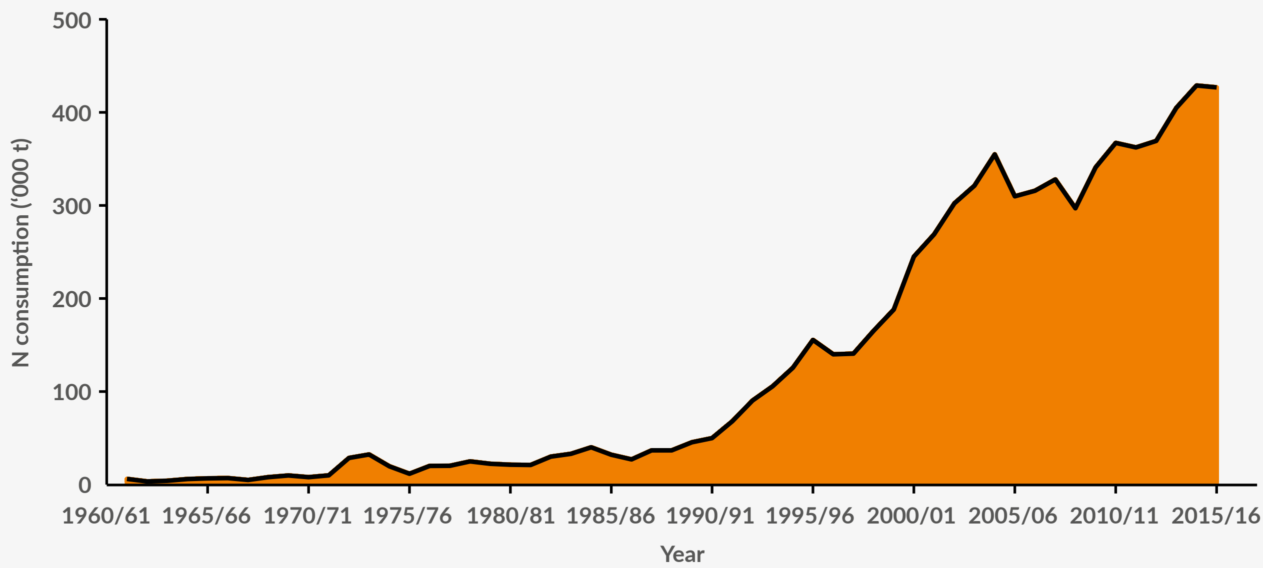


**Figure 2: Change in nitrogen consumption ('000 t) in NZ from 1961/62 to 2015/16.**
*Source: Data provided by the NZ Fertiliser Association*

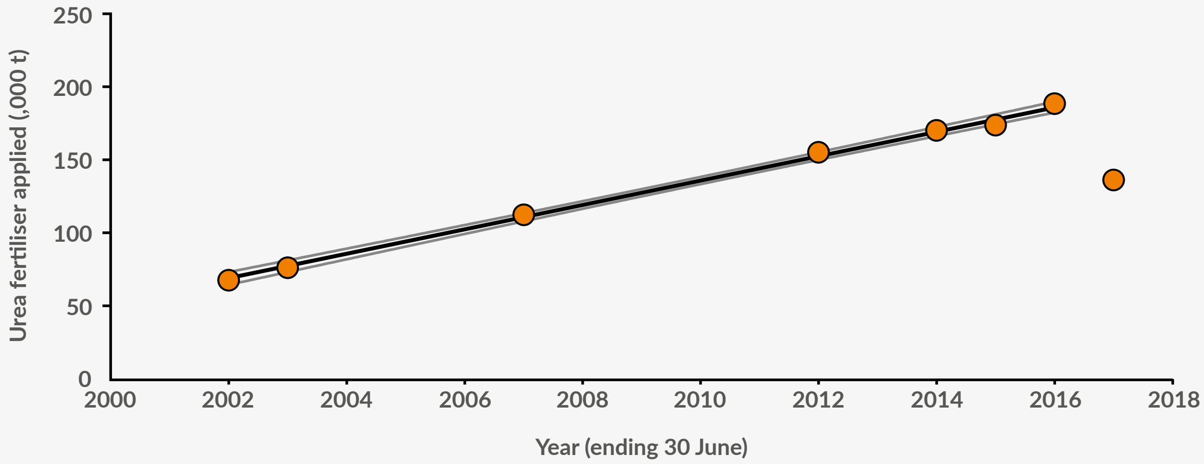


**Figure 3: Urea fertiliser (,000 t) applied in Canterbury, NZ from 2002 to 2017.**
*Source: Data from Statistics New Zealand*

Assuming that herbage is about 3.5% N, then ~700 kg N is required from all sources (mineralisation, fixation animal returns and N fixation) to meet the pasture demand. This yield response has led to an increase in N fertiliser use in Canterbury alone of approximately 8,500 t/yr every year between 2002 and 2016 *(Figure 3)*. When applied appropriately, this N fertiliser aids recovery after grazing and ensures light interception is maximised. There are inevitable losses of N to the atmosphere through volatilisation when it is applied. However, most N loss in dairy systems comes from the high N loading in urine patches which is in excess of the plant's demand, and this has been well documented elsewhere.

The application of inorganic N pushes the balance of a traditional ryegrass/white clover pasture towards the grass component. The incursion of clover root weevil also targeted the clover and for many dairy farmers clover is now a bonus when it appears in their ryegrass dominant, N fertilised pastures. As shown by Gerald Cosgrove in 2005, white clover content in dairy pastures needs to be above 30% to promote significant responses in milk production and for many farmers the variability of its presence has led to greater reliance on inorganic N.

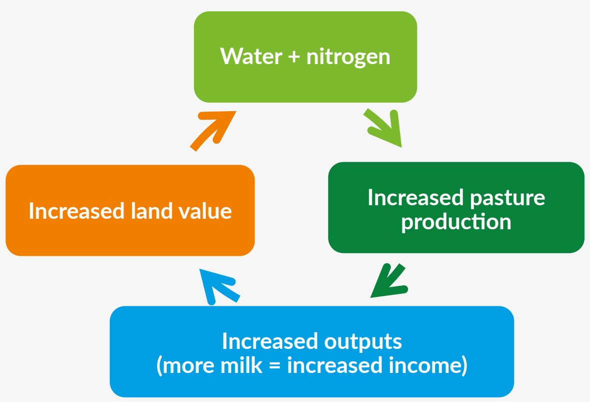


**Figure 4: Intensification loop between inputs and product outputs.**

**Biological limits of production systems**

A feature of the high yields generated from N fertiliser is that it creates an intensification loop *(Figure 4)*. The higher pasture yield promotes milk production and therefore higher financial returns. In a market situation the consequence is higher land prices which, to maintain the required levels of return, lock in the need for high levels of N fertiliser to maintain production and returns on investment. This intensification has driven land prices in Canterbury, and their recent levelling off *(Figure 5)* has in part been because the biological limits of these production systems have been attained.

The same biological limits that have been overcome by inorganic N use on dairy farms apply in sheep, beef and deer farming. The inability to control grazing as effectively as on dairy farms means that these systems are often low in legumes, which are preferentially grazed during set stocking, and thus pastures become grass (carbon) dominant. They frequently develop a thatch of dead material overlying the soil surface. As noted by Fasi et al. in 2008, this reduces N cycling and means single N fertiliser applications can produce up to 40 kg DM/kg/N applied, which is significantly higher than the 10:1 ratio expected in higher fertility dairy pastures.

The extent of N response can be seen from the data in *Table 1*. The 15.8 t DM/ha produced from only the addition of N fertiliser shows the yield potential of Canterbury dryland pastures without the addition of any water. Similar significant yield gaps exist on all hill and high country farms where the utilisation of available water is severely limited by N supply. Challenging farmers to focus on using that available water as efficiently as possible through the introduction of appropriate legumes has been the focus of the Dryland Pastures Research team at Lincoln University for the last 20 years.

The overriding driver of our research focus has been to consistently grow lambs at ~300 g/hd/day from birth for 100 days to ensure they are ready for slaughter before the summer dry kicks in. This has been achieved

Plantain and red clover

Sub clover

Red clover

White clover

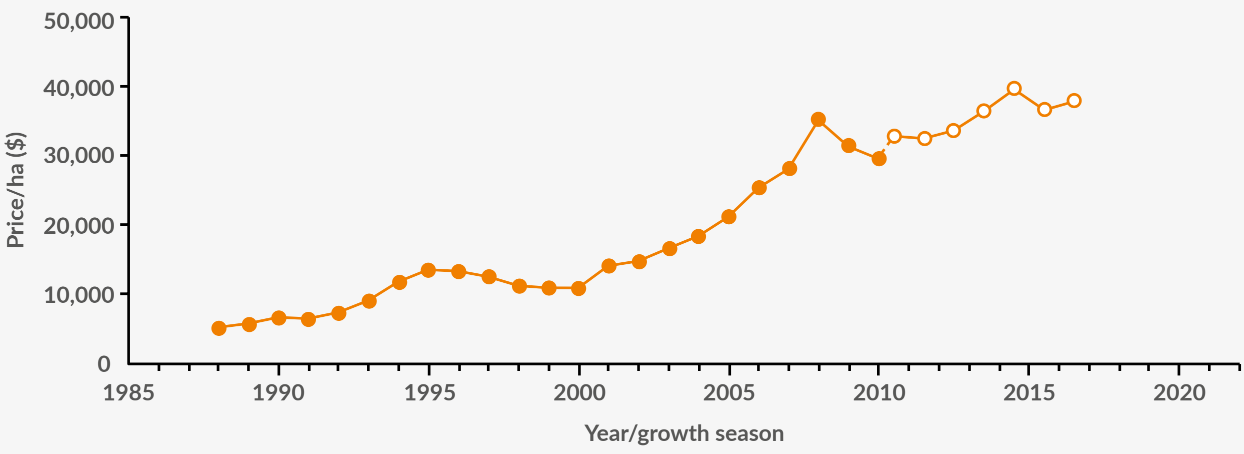


**Figure 5: Change in the price ($/ha) of dairy land in NZ**

*Source: Data from DairyNZ New Zealand Dairy Statistics (www.dairynz.co.nz/publications/dairy-industry/). (QV.co.nz 1988-2010, REINZ 2009/10-2016/17)*

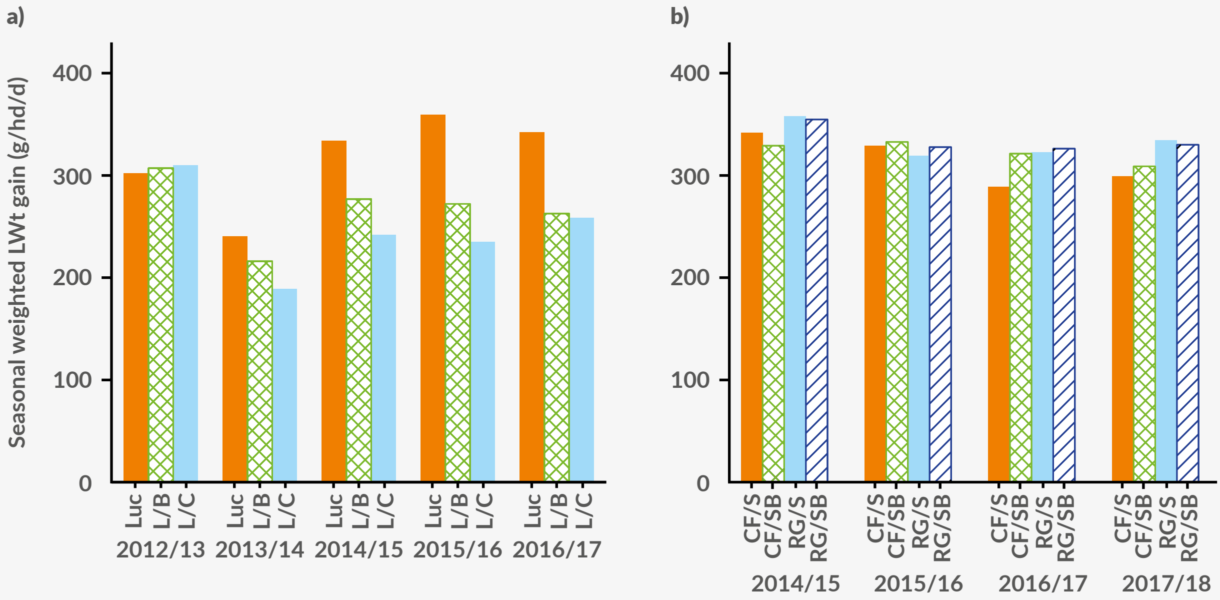


**Figure 6: Weighted seasonal liveweight gain (g/hd/d) of twin lambs prior to weaning grazing: a) dryland lucerne monocultures (L), lucerne/brome (L/B) or lucerne/cocksfoot (L/C) mixes over five years; and b) grazing dryland cocksfoot (CF) or ryegrass (RG) pastures established with subterranean clover (S) or subterranean and balansa clovers (SB) at Ashley Dene, Canterbury.**

**The success of implementing a legume-based grazing system takes longer than the immediate fix to a short-term pasture deficit situation provided by N fertiliser. Once the whole system has been developed, however, the production rewards are tangible and locked in at a relatively low cost.**

on very stony Lismore soils at Ashley Dene, which are soils with some of the lowest water-holding capacities in New Zealand, using lucerne and sub clover-based pastures *(Figures 6a and b)*. These results highlight the potential that exists for large areas of dryland farming in New Zealand.

### Lucerne

Taking the fundamental principle 'all plants are N deficient all the time – except those that fix N' – the research focus has been on determining which legume is most appropriate for the situation and how do we make it thrive? Also, importantly, how can we create farm systems to allow farmers to make money from it?

The high-profile success at Bonavaree of a lucerne-based system is highlighted in *Table 2*. In this case Doug Avery became a farmer of water – by utilising the legume that he already knew grew successfully in his environment. The herbage production advantage came from having a deep-rooted legume that is never N deficient, so maximises the available soil water, particularly in spring. Therefore, it always grows more than N deficient grass-based pastures in the same environment. The direct feeding of lucerne to ewes and lambs required significant management changes, but is now routine across this and many other dryland farms.

**Table 2: Changes in key performance indicators of farms system productivity at Bonavaree in Marlborough over a 10-year period resulting from transformational change based on a move to direct grazing of dryland lucerne and landscape farming practices.**

| | 2002 | 2012 | CHANGE |
|---|---|---|---|
| Land area (ha) | 1,100 | 1,800 | ↑ 64% |
| Sheep numbers | 3,724 | 4,158 | ↑ 12% |
| Lambing (%) | 117 | 145 | ↑ 24% |
| Lamb weights (kg) | 13.3 | 19 | ↑ 43% |
| Lamb sold (kg) | 38,324 | 74,460 | ↑ 94% |
| Wool (kg) | 18,317 | 20,869 | ↑ 14% |
| Sheep:cattle | 70:30 | 50:50 | |
| Gross trading profit (ha) | $317 | $792 | ↑ 149% |

*Source: Moot & Avery, 2013*

Lucerne was grazed by many farmers in New Zealand in the 1980s, but this was usually by weaned lambs after a first cut for hay. Therefore, the benefits to ewes grazing lucerne and rumen adjustment by lambs were limited. The animal performance results were less compelling than is possible with the more flexible lucerne management advocated today. The higher feeding value of the lucerne over N deficient grass provides a protein-rich feed source for lactating ewes and then weaned lambs.

**We need to make legumes thrive to overcome the weakest link in our pastoral systems – a lack of N. The meat, milk and wool that result are simply a by-product of overcoming that weakest link, which allows animals to be fed more effectively.**

The ewes retain their condition through lactation and then are heavier than they were historically at tupping. The additional ewe weight leads to greater conception and increased lambing percentages. The system has required new skills to manage a high-quality forage and maintain flexible stocking policies to take advantage of the additional feed grown in wetter-than-average summers.

### Advantages of legume-based grazing systems

The success of implementing a legume-based grazing system takes longer than the immediate fix to a short-term pasture deficit situation provided by N fertiliser. Once the whole system has been developed, however, the production rewards are tangible and locked in at a relatively low cost. This can be illustrated graphically by the changes that have occurred at Bog Roy Station near Otematata (420 mm rainfall) over the last decade *(Figure 7)*.

Initially, the system changed to direct feeding merino ewes and lambs on lucerne. The production benefits saw an immediate lift from 2008 to 2011, with an extra 20 tonnes of weaned lambs, but little change in ewe numbers. The lucerne grazing meant the ewes were being better fed during lactation so lambs grew faster and were heavier at weaning for sale. A flow-on effect is then seen in the next three years when more ewes were mated and at heavier weights, because there was more feed grown across the farm, particularly on the hills when the lucerne was being grazed.

As the areas of lucerne grew, there was a need to set stock the lucerne for a short period during lambing, and new management skills were required. In this case, set stocking is carefully managed for a short period of time to avoid compromising the lucerne. By 2016, 50 tonnes more lamb meat was weaned than in 2008, and an existing small irrigation consent has been transferred to allow the development of a centre pivot irrigated block that can be used for finishing those weaned lambs. The system has evolved over 10 years, with reduced supplementary feed made and fewer animals retained over winter. Direct feeding of lucerne now drives animal production and it is planted wherever possible.

### Sub clover

In dryland areas where the cultivation of lucerne is not possible, managing hill country through targeted grazing management can also achieve impressive results. In Marlborough, David and Jo Grigg at Tempello identified subclover as the legume of choice to provide the high-quality feed and N input their predominantly uncultivatable hill country required.

They report similar success with increased lamb weights, and higher condition ewes and cattle providing a buffering role to deal with unruly explosions of pasture growth in late spring and summer. Their template can be replicated across other dryland properties, where subdivision and stock water are the keys to being able to improve pasture legume content and therefore pasture quality. They

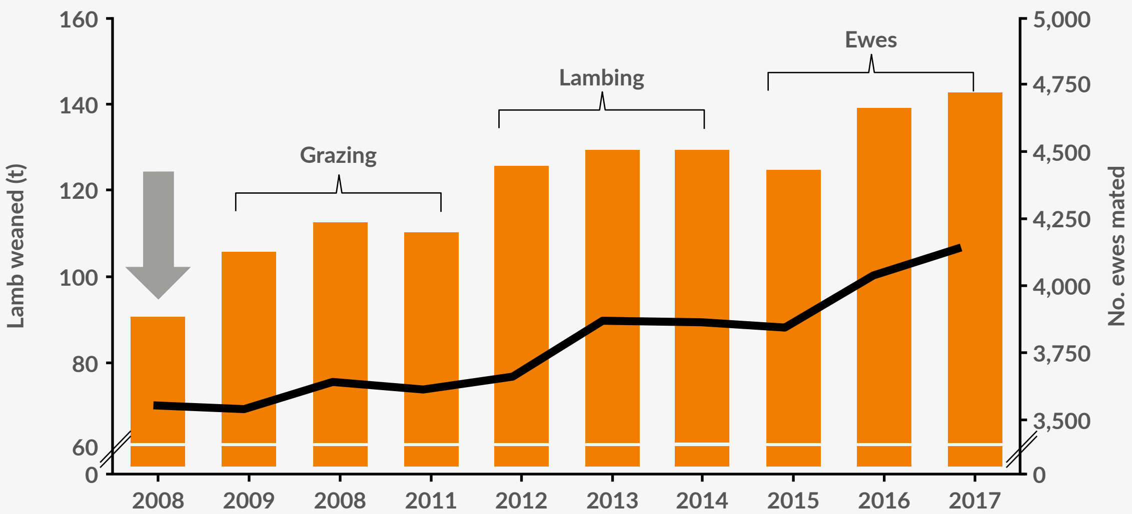


**Figure 7: Transformational changes in lamb meat (t/yr) produced and the number of ewes mated at Bog Roy Station from 2008 to 2017 in response to integrating a lucerne-dominant grazing system and modifying grazing management to enhance system performance. The grey arrow indicates baseline production from a grass dominant system prior to initiating change.**

Table 3: Change in production parameters at Tempello in Marlborough from 2001 to 2016.

| | CORRIE/POLL DORSET FLOCK | | | 90% CORRIE FLOCK* |
|---|---|---|---|---|
| Production measure | 2001 | 2003 | 2007 | 2016 |
| Ewe tupping weight (average kg/hd) | 63 | 65 | 71 | 70 |
| MA scanning % | 145 | 148 | 165 | 178 |
| 2T and MA lambing % | 128 | 128 | 138 | 135 |
| Lamb growth rate pre-wean (g/hd/day) | 250 | 374 | 345 | 295 |
| Average lamb weaning weight (kg/hd) | 27 | 30.9 | 33 | 35 |
| Lamb weight/ewe weaned (kg) | 34.5 | 39.5 | 45.5 | 47.3 |
| % prime at weaning (over 32 kg/hd) | 50 | 75 | 85 | 89 |
| SU wintered/ha | 8.2 | | | 11.5 |

returned an extra 16 t/yr of meat, with an increase in mixed age ewe lambing percentage, the ability to carry more stock, improved lamb growth rates and weights leading to 89% prime (>32 kg) lambs at weaning *(Table 3)*.

## Red and white clover with plantain

For moister areas, or for irrigated finishing farms, the combination of red and white clover offers the same opportunity as the other legumes in a dryland environment. The animal production gains from summer feeding of plantain-based pastures with these legumes have been well documented by Professor Peter Kemp's group at Massey University. What is often missed in examining animal production in controlled on-station environments is the earlier production from all legumes in spring than frequently occurs from N deficient pastures in hill country.

Recently, John Chapman at Inverary Station in the Ashburton Gorge highlighted this earlier-than-expected growth of his red clover-based pastures as an unexpected benefit of his development programme. His flat free-draining land is suitable for lucerne, but the heavier, wetter hills utilise red clover. By oversowing pure legumes on sprayed-off steeper hill country, after initially breaking down the grass thatch with stock, he is able to minimise soil erosion, control thistles and then introduce plantain or cocksfoot in later years to extend the life of his renovated 'spray and delay' pastures.

## N deficiency a major impediment

These examples of legume-based farming systems are all based on recognising that N deficiency is the major impediment to hill country sheep and beef farming – and actually all farming systems as outlined above. As noted by Lucas et al. in 2010, the legumes consistently fix about 30 kg/N per tonne of above-ground legume grown and provide feed with an ME of greater than 11 MJ/kg DM and crude protein above 24% for most of the year.

Legumes do not require additional N fertiliser, but it can be used on the shoulders of production seasons to boost grass growth, provided the extra feed grown is eaten and not left to shade the legumes. There are a range of other legumes now available on the market including arrowleaf, balansa and Persian clovers, and farmers will determine which (if any) of them are suitable for their farm situation.

It should be noted that lucerne and sub clover, which have transformed many dryland farms in the last 15 years, have been around for many years. I was reminded of this by the Minister for Primary Industries when meeting him recently. I was too polite to respond that it is not the plant by itself that produces a transformation – it is the farm system that is developed around it.

We need to make legumes thrive to overcome the weakest link in our pastoral systems – a lack of N. The meat, milk and wool that result are simply a by-product of overcoming that weakest link, which allows animals to be fed more effectively. The opportunities exist for further legume development, particularly on sheep and beef farms, and this is the focus of a recent Beef + Lamb NZ funded programme on 'Regenerating Hill Country' which is the basis of our current research.

Re-engaging with legumes appears to be the lowest hanging fruit for much of our pastoral landscapes – it remains to be seen how abundantly we are able and allowed to pick it.


## Acknowledgements

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## Further reading


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