Transforming dryland sheep and beef farms – a scientists view

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Summary

Transformation of vulnerable east coast sheep and beef farms into thriving resilient businesses has been the aim of a dedicated dryland research programme at Lincoln University for the last 20 years. Our research confirmed a major nitrogen limitation in these pasture systems. This restricts plant productivity, water use efficiency and consequently animal performance. Research was initiated to understand how a higher proportion of legumes could be integrated into these farm systems. The outcome has been a sustainable method of farm improvement for farms in some of the most drought prone regions of New Zealand. Technically, research on the growth and development of lucerne in relation to its biophysical environment was the initial focus. This has enabled greater flexibility in its spring grazing management to enhance animal growth rates during lactation. The complementarity of subterranean clover to provide late winter and early spring growth, and the role of other annual legumes has also been investigated. A parallel extension programme has emphasised the importance of the quality of feed provided by legumes and their ability to maximise water use efficiency. The outcome has been demonstrated financially, socially and environmentally. Lucerne seed sales have increased from 20 to 200 tonnes over the last decade and farmers have reported a consistent ~30% internal rate of return on investment for a lucerne conversion.

Key words: *Alfalfa, Medicago sativa, technology transfer, Trifolium subterraneum*

Introduction

The dominant mountain chain running through New Zealand splits the country in two climatically. The drier eastern regions experience 300–1000mm of annual rainfall and potential soil moisture deficits of up to 500mm (Salinger 2003). In most years, winter rainfall replenishes soil moisture to field capacity so spring growth is reliable and responds as temperatures rise. However, the vagaries of summer rainfall means dryland farming practices have been naturally conservative. They have relied on selling as many lambs prime as possible but off-loading the rest as 'store' to lowland finishing areas. To increase reliability of pasture supply the area of irrigation has expanded rapidly in the last 20 years, particularly across Canterbury with over 230,000 ha of new irrigated land. This has resulted in an increase in dairy cow numbers from 113,000 to 1.33 million (Figure 1a). At the same time the number of sheep in Canterbury has halved from 10.4 million to five million (Figure 1b). The dairy expansion has offered opportunities for lowland farmers to receive cash income from contracts to graze dairy heifers or provide winter feed for the dried off herds. As a consequence, the land available in summer for finishing store stock has diminished. In addition, store lamb prices frequently drop in response to the oversupply of lambs as many farmers in a given area are forced to destock at the same time, by the onset of summer dry.

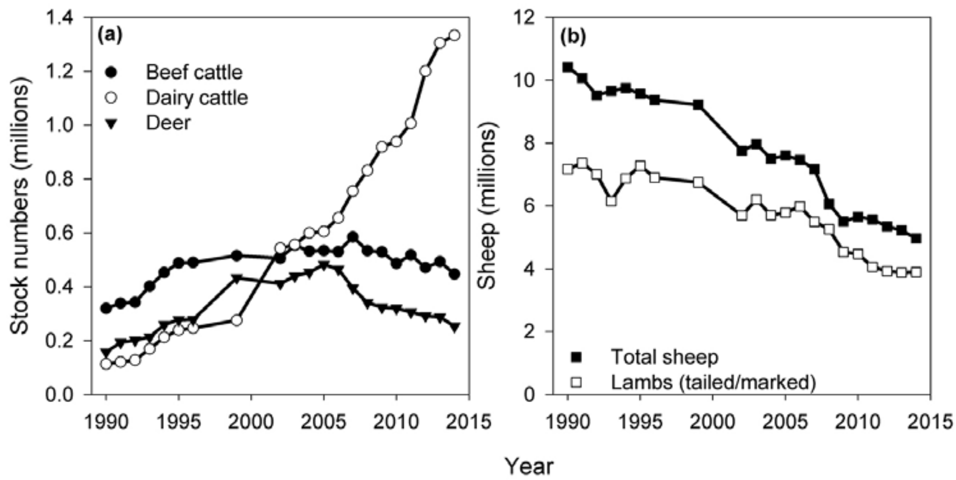

Figure 1. Change in (a) beef cattle, dairy cattle and deer (b) sheep numbers (millions) in the Canterbury region between 1990 and 2014. This work is based on/includes Statistics New Zealand's data which are licensed by Statistics New Zealand for re-use under the Creative Commons Attribution 4.0 International licence.

The lack of demand for store stock leads to dryland farmers accepting low prices, buying in feed, overgrazing and/or attempting to finish a larger proportion of their own stock on farm. This has follow-on consequences for other stock classes, particularly ewes. However, finishing lambs provides an opportunity to maintain some control of the production process and reduces reliance on volatile trading markets. To do this requires a reassessment of the temporal feed supply on farm and greater understanding of the biophysical factors that influence its growth on dryland pastures. The recognition that dryland east coast farmers were vulnerable to variable climate and climate change, plus the lack of other research providers in the space, meant a dedicated dryland pastures research programme was initiated at Lincoln University in 1996 (Moot 2014). The remainder of this review outlines the underpinning science, on-farm adoption and current research aimed at transforming dryland pastoral farms in New Zealand.

Science and extension questions

To create a credible and relevant case for transforming dryland farm systems required answers to several key science questions. Initially these involved understanding the biophysical influences on pasture production, followed by specific issues related to lucerne grazing management which are ongoing.

Biophysical response of pasture production on dryland farms

The impact of irrigation water and nitrogen on dryland pasture production were investigated for a nine year old cocksfoot (*Dactylis glomerata* L.) sward at Lincoln University (Mills *et al.* 2006, Mills *et al.* 2009). Cocksfoot is recognised as being persistent under dryland conditions (Mills *et al.* 2014) and it is the second most commonly sown species in New Zealand. Results from this experiment highlight the relative importance of water and nitrogen to dryland farmers. The unirrigated and unfertilised control pasture averaged 6.3t ha (Mills *et al.* 2006) and this represents a typical pasture production profile for dryland farms (Rickard and Radcliffe 1976). The addition of unlimited irrigation water to the dryland pasture is indicative of the immediate change produced by the addition of irrigation water to previously dryland areas. Essentially it represents the change that occurred across the Canterbury Plains with the development of centre pivot irrigation. In this situation the yield increased to 9.8t/ha/yr, which is consistent with historic levels for irrigated pasture in Canterbury (Rickard and Radcliff 1976). However, the greatest yield response was seen with the addition of nitrogen fertiliser. This alleviated the most limiting factor in these dryland systems. For the unirrigated pastures with N added, yields averaged 15.1t DM/ha. The provision of inorganic N increased yield by accelerating growth rates during the periods when water was available. The depletion of soil water was effectively the same under the fertilised and unfertilised pastures so the water use efficiency of fertilised pastures increased 250% (Mills 2007). The importance of nitrogen in pasture production is also highlighted by the irrigated plus nitrogen treatment. Here the annual yield has increased to 21.9t/ha/yr. Given these results, it is hardly surprising that the use of inorganic nitrogen has increased in New Zealand over the last 20 years (Figure 2). The implication for dryland farmers is that increased use of nitrogen in their pasture systems can significantly increase total pasture production.

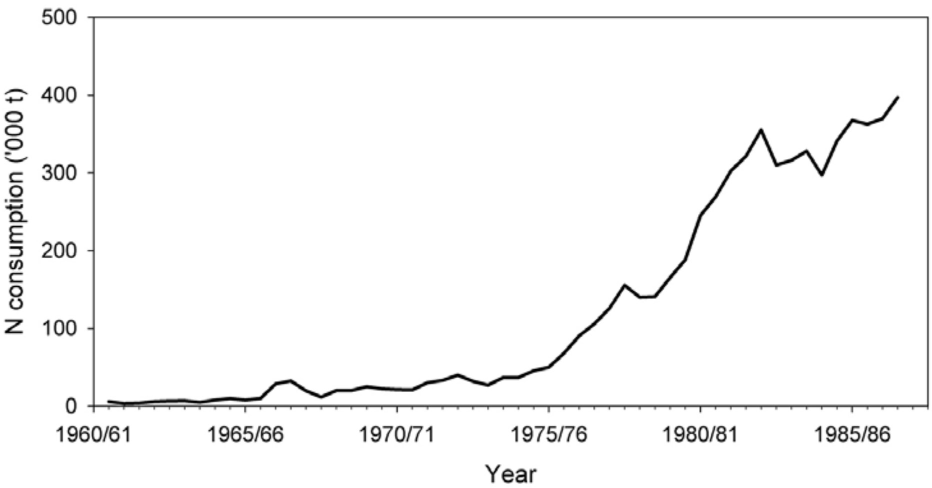

Figure 2. Total quantity of nitrogen (N) sold annually in New Zealand (New Zealand Fertiliser Association 2015 pers. comm)

The wholesale application of inorganic fertiliser may overcome the fertility constraint but is unlikely to be acceptable from a sustainability perspective in dryland systems, requires changes in stock policy to eat the additional feed grown, and is comparatively expensive given most of the fertiliser is imported. Therefore our research programme focussed on transforming dryland pastures by using legumes to provide the nitrogen into the system. Additional benefits of legumes include superior animal preference and performance in a grazed system.

Which legume?

The most widely grown and utilised legume in New Zealand is white clover (*Trifolium repens*). It has been used in most dairy areas and in wetter (>1000mm rainfall) regions to provide high quality feed and nitrogen through fixation. However, it fails to survive in dryland farm systems because its taproot dies after about 18 months (Westbrooks and Tesar 1955, Brock *et al.* 2003). It then regenerates from seed or nodal roots but its contribution to the pasture sward is variable on an annual basis (Knowles *et al.* 2003). In contrast, a survey (Kirsopp 2001) found farmers recognised the importance of lucerne (*Medicago sativa*) as a deep tap rooted legume but were predominantly using it to cut and carry in spring. It was not being grazed in spring because it hadn't reached '10% flowering' and farmers were reluctant to put stock onto fresh herbage. The superiority of lucerne in production and persistence over red clover (*T. pratense*) and chicory (*Cichorium intybus*) was established in irrigated and dryland conditions (Brown *et al.* 2005).

The focus for lucerne research was then to develop grazing management rules that would increase its direct consumption on farm. A series of targeted experiments highlighted differential patterns of carbon and nitrogen remobilisation and accumulation in the perennial storage organs of lucerne in spring and autumn (Moot *et al.* 2003, Brown *et al.* 2006, Teixeira *et al.* 2007). This enabled a flexible grazing management plan to be developed and promulgated based on the growth and development of the crop (Moot *et al.* 2003). In particular, the remobilisation of stored nutrients to spring shoot growth meant feed supply was being increased in spring at a time when feed demand was maximal, during lactation. The ability to graze ewes and lambs on lucerne, has given consistent pre weaning live weight gains of ~300g/hd/day at stocking rates of 12–14 ewes plus twin lambs (Table 1). Remobilisation also increased spring water use efficiency (Moot *et al.* 2008) because the legume was not nitrogen deficient. The importance of flowering was switched from spring to autumn to provide a visual cue for farmers to 'rest' the lucerne and allow the recharge of underground reserves.

Implementation

The change in lucerne grazing management has led to significant practice change in some of the driest areas of New Zealand. In 2008 the transformation of a failing dryland farm was highlighted at the New Zealand Grassland Association conference (Avery *et al.* 2008) and other field days. This example highlights positive production and environmental outcomes from using lucerne as the primary feed source. This has created a resilient farm system that is now financially viable and has doubled animal production (Table 2) (Moot and Avery 2013) while the farm has won environmental and farming awards. Equally, the success of a grazed lucerne system on a high country merino property was documented by Anderson *et al.* (2014). The overall success is reflected in an increase in imported seed sales from 20 to 200t/yr (Monk *et al.* 2016) and the development of extension tools online and electronically to assist farmers to make the transformation (Moot 2014).

Not every property has the opportunity to utilise lucerne as the main feed source over a large area of their farm. For some other legumes have provided the high quality forage used to efficiently utilise precious spring moisture with emphasis on the annual legumes (Anderson 2013). On 'Meadowbank' a significant lift in animal performance has been achieved through the introduction of a range of a range of annual legumes (Table 3), while subdivision and improved grazing management of subterranean clover were the key to a production lift on 'Tempello' (Table 4). The potential to utilise sub clover over a range of dryland farm systems is the subject of a current research programme (Dryland Pastures Research Tea 2015, Moot *et al.* 2016b).

		Lambs at foot				Lambs at foot					
Exp and No. years		Mean LWG	Min LWG	Max LWG		Mean LWG	Min LWG	Max LWG	Average SR	Min SR	Max SR
Max Clover		307	288	326	23.7	202	187	217	37		
2 to 8 years						179	133	238	31.6	21.5	39.5
						133	22	195	24.6	17	28.5
H7		294	244	363							
6 years						247	213	286			
Max Lucerne		274	244	304							
2 years						219	199	239			

Table 1. Mean, minimum (Min) and maximum (Max) live-weight gain per head (LWG, g/hd/day) for lambs at foot (lactation phase, pre-weaning) and weaned lambs from three dryland grazing experiments conducted by the Dryland Pastures Research Team at Lincoln University or Ashley Dene Systems Research Farm in Canterbury. Mean, minimum and maximum stocking rates (SR; animals/ha) are reported. Stocking rates varied to match feed supply with animal demand to maximise live-weight production per hectare rather than Live-weight production per animal. Generally, hoggets grazed in autumn as lambs had reached target weights or were kept as replacements

	2002	2012	Change (%)
Land area (ha)	1100	1800	(+) 64
Sheep numbers	3724	4158	(+) 12
Lambing (%)	117	145	(+) 24
Lamb weights (kg)	13.3	19.0	(+) 43
Lamb sold (t)	38.3	74.5	(+) 94
Wool (t)	18.3	20.9	(+) 14
Sheep:cattle ratio	70:30	50:50	
Gross trading profit (ha)	$344	$833	(+) 142

Table 2. Change in production at 'Bonavaree', Marlborough over 10 years after initiating a transformational change based on a landscape farming approach (Moot and Avery 2013, Moot and the Dryland Pastures Research Team 2013)

	2005	2012	Change (%)
Ewe Lambing %	121%	142%	(+) 21
Hogget Lambing %	60%	81%	(+) 21
Weaning weight	28kg/hd	34kg/hd	(+) 21
Return	$730/ha	$2640/ha	(+) $1910/ha (>260%)

Table 3. Changes in key stock performance indicators at 'Meadowbank' from 2005 to 2012 after introduction of alternative legumes to modify quantity and quality of feed on offer (Grigg 2013)

	Drought (900 kg DM/ha) Low grass/Low legume	Grass dominant (<5% legume)	Ideal legume (up to 60% sub clover)
Weaning weight (kg/hd)	27	30	34
Value*	$81	$90	$113–$130
Gain ($/hd)	0	9	32–49
Over 2200 lambs ($)	-	19,800	70,400–107,800
Return/ha gain**	-	$33	$117–$179
Note: *Assumes prices as $3/kg store and $6.80/kg killed, **on the basis of an area of 600ha.			

Table 4. Comparison between key performance criteria in a Corriedale and Corriedale/Perendale stock system from a 600ha key lamb production area on 'Tempello' based on 2011 lamb prices in a drought situation (low pasture cover), an average year with grass dominant low quality pasture cover (pre subdivision) and a post pasture improvement situation with 60% subterranean (sub) clover on offer in spring (Grigg and Grigg 2012)

Current research questions

The introduction of a high legume diet into dryland systems has also led to a series of ongoing research questions. Animal production is at the forefront of farmers questions and results from recent experiments are summarised in Table 1. Importantly animal health issues are also of concern to farmers who change to a legume based diet. This means extension (Moot 2014) includes guidance on grazing management has dealt with redgut, bloat, clostridial disease, grain supplementation, and phytoestrogens. There is little recent research related to most of these topics so advice from the 1980s is being recycled while new data are generated. Some issues being addressed include the impact of grain supplementation (Moot *et al.* 2016a), reasons for elevated phytoestrogen in lucerne (Fields *et al.* 2016) and the potential to set stock lucerne for four to six weeks in spring.

Conclusions

To transform dryland pastures systems has required an understanding of the basic science, validation of the science in field demonstrations and adoption on farm to develop credible case studies. The latter is an important component that leads to on-farm adoption but it requires ongoing science support and extension. The science focus has emphasised the farming of water as the basis for dryland systems. Legumes, to fix nitrogen and supply high quality feed, have been successfully integrated from an applied science programme into farm systems. Ongoing issues associated with animal performance and health, refinement of grazing management and the role of alternative legumes are being addressed. The research has delivered resilient dryland farms capable of successful environmental and financial outcomes in our driest areas subject to the greatest variability of current climate.

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Dryland Pastures Website: www.lincoln.ac.nz/dryland

Dryland Pastures Blog: www.blogs.lincoln.ac.nz/dryland

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