

Climate Change Adaptations on Sheep and Beef Farms: A case study investigation

Phil JOURNEAUX¹, Anita WREFORD² and Derrick J MOOT²

¹ *Journeaux Economics, 7 Masters Road, RD 7, Hamilton, New Zealand 3287*

² *Lincoln University, Ellesmere Junction Road, Canterbury, New Zealand*

*Corresponding author: phil.journeaux@agecon.co.nz

Abstract

Climate change and an increase in climate variability over preceding decades, has meant that farmers needed to adapt their farming system to accommodate this. This paper reports on eight case study sheep and beef farms which were analysed as to the changes they have made, and the impacts of these changes on the farm system, profitability, and biological greenhouse gas emissions. The farmers were interviewed about their changes, the drivers behind these, their observations of changes in climatic conditions, and the impact on the profitability of their farm business. The farms were then analysed using Farmax to quantify the impact of these changes on financial and productivity metrics. In most cases, the key objective for the farmers was to develop a more flexible farm system to cope with climatic variability, while at the same time ensuring the farm business remained profitable. Overall, the changes involved improving both the efficiency and productivity of the system, development of the farm, i.e. more subdivision, a change in forages, an increase in trading stock, especially cattle, and for several an increase in the area planted in lucerne.

Keywords: climate change, climatic resilience, farm system flexibility

Background

Since 1990 productivity and land use changes mean total biological greenhouse gas (GHG) emissions from the New Zealand red meat sector have declined by 30% and emissions per unit of product by 40% (Ledgard 2017; Moot and Davison 2021). The reduction in absolute emissions has resulted from land use change from pastoral farming to forestry and the conversion of traditional sheep country to (often) irrigated dairy land, particularly in Canterbury. This has reduced sheep numbers from over 40M in 1990 to fewer than 25M currently. However, over the period 1990 to 2021 the national lambing percentage increased from 100 to 130% and lamb carcass weight increased by ~3 kg/hd (Moot and Davison 2021) which have contributed to the reduction in emissions intensity. Examples of productivity changes have been documented in several farm case studies that have identified the use

of appropriate legumes, resulting in higher dry matter production, as a significant driver of profitability over time (Avery et al. 2008; Grigg et al. 2008; Moot et al. 2024; Tayler et al. 2016). For summer dry regions the traditional ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture has failed to persist (Knowles et al. 2003) which has resulted in the increased use of lucerne (alfalfa; *Medicago sativa* L.) and subterranean (sub) clover (*T. subterraneum*) as well as other more drought and heat-tolerant species such as cocksfoot (*Dactylis glomerata*) and tall fescue (*Festuca arundinacea*). The integration of these species into farm systems has required the development of specific management packages (Moot et al. 2024; Olykan et al. 2019) and a focus on extension for adoption.

In areas considered “summer safe” with more reliable summer rainfall, the use of herb/legume mixes has shown similar increases in productivity (Chapman et al. 2021). There has also been an increase in the percentage of dairy/beef cattle slaughtered (Moot and Davison 2021), and changes in cattle to sheep ratios along with continued subdivision of hill country regions that have improved grazing management.

Over the last few decades, farmers have had to contend with the reality of a changing climate. In response, many have adjusted their management systems to mitigate these impacts (Gray et al. 2008). At the same time, climate related issues, particularly in summer dry regions in the east of New Zealand, have contributed to increasing economic pressures. This has meant that farmers have had to improve the efficiency of these systems to maintain or improve profitability (Beef + Lamb NZ, 1990-2021).

In 2023 a 3-year study, funded by MPI, was initiated by Lincoln University: *Evaluation of Primary Sector GHG Adaptation Case Studies*, with the objective of evaluating current adaptation practices including costs and benefits, long-term suitability and the effects on greenhouse gas emissions, on a range of case study farms and orchards. Within this, the sheep and beef sector was included, with eight sheep and beef farms identified and consenting to be case studies. Farms were selected that had made significant management changes over the last two decades so that the impact of these changes could be assessed over time in relation

to productivity, profitability and their farm emissions profile. This paper discusses the results from the interviews and resultant analysis of the farm data.

Approach

The methodology for the initial component of the study was:

- Suitable farms were identified and then approached to take part in the study. Suitability was assessed by the authors based on their knowledge of farms which had shown a significant change in their farm system at some stage in the last 20 years.
- Having consented to take part (Lincoln University Human Ethics Committee HEC2023-48), the farmers were then interviewed in person, with the interview questions covering:
 - Farm ownership background
 - Farm system in previous years
 - Current farm system
 - How the climate has changed
 - Impact/frequency of adverse climatic events
 - Adaptations carried out
 - Barriers to change
 - Information and advice sought and from whom
 - Costs associated with any change
 - Change in stock numbers and performance
 - Future outlook
- The farm was then analysed via Farmmax, as to the previous system as well as the current system, to compare production levels, profitability, and biological GHG emissions. Current schedules and farm working expenses were used for both years.
- The interview and analysis were written up and then checked back with the farmers.

Case Study Farms

Eight case study farms were involved, located around New Zealand (Figure 1).

Farm #1. Northland based, originally running a traditional breeding ewe/breeding cow operation. The key adaptation made, with respect to the farm system, was the reduction in sheep offset by an increase in beef. With the changing climate the farmer noted, “*sheep became too much work, particularly in the humid climate, as they were susceptible to flystrike, internal parasites, and facial eczema. Overall, the bulls, run under a techno grazing system, offer a much more flexible and profitable system, which is more suited to the climate variability*”. Some areas have also been planted in forestry. In a dry summer/drought, the main strategy is to feed baleage and sell down the bulls at lighter weights.



Figure 1 Locations of the eight case study farms.

Farm #2. Wairarapa based, originally running a traditional breeding ewe/breeding cow operation, with most progeny sold store. The key adaptations made were the reduction in the stocking rate (by 4%), and fewer sheep relative to cattle, with the sheep:cattle ratio moving from 80:20 to 60:40. Another key adaptation has been the introduction of sub clover, which survives droughts by annual reseeding, and provides more and higher quality feed. The reduced stocking rate allowed for significantly more finishing of stock, reducing the exposure to the store market, along with an increase in the number of animals (mostly beef) being traded.

Farm #3. Wairarapa based, originally running a traditional breeding ewe/breeding cow operation, with most progeny sold store. The key adaptations made were a reduction in breeding ewes (by 33%) but increased lambing percentage with most progeny finished, the breeding cows replaced with trading cattle selling most as stores, an increase in the area of forage crops providing feed over the summer, and the introduction of sub clover which has lifted both pasture quantity and quality.

Farm #4. Marlborough based, originally running breeding ewes for fine wool, plus some breeding cows. The farm has switched its sheep breed (from a fine wool breed to a more dual purpose breed), with a high lambing percentage and selling lambs largely finished. Breeding cows have reduced by 48%, largely replaced by trading cattle (steers and bulls – refer Table 1 below),

a large area planted into lucerne for grazing, plus an area planted into (more heat tolerant) tall fescue, and a brassica forage crop (*Brassica oleracea* L.) is grown for summer feed, plus areas also planted into forestry, and a horticultural development.

Farm #5. Hawke's Bay based, originally running a traditional breeding ewe/breeding cow operation, with all progeny sold store. The farm has expanded in area, as a means of achieving economies of scale – not directly related to adapting to climate variability, with the key adaptation being a complete switch into a trading unit finishing lambs and bulls, with a significant area (15% of the farm) in forage cropping to smooth out the feed supply and provide options around finishing times.

Farm #6. South Canterbury based, originally running predominantly breeding ewes (Corriedales) and some breeding cows. The adaptations made include a significant development programme across the farm (e.g. subdivision, oversowing of new pasture species), development of a significant area into lucerne for grazing, development of an irrigation system, which is used to irrigate lucerne/pasture mixes made up of: lucerne, prairie grass (*Bromus cartharticus* Vahl), white clover, chicory (*Cichorium intybus* L.), and plantain (*Plantago lanceolata* L.). As a result, the farm is now running many more ewes (Merino) and breeding cows, with most progeny finished.

Farm #7. Northern Southland based, running breeding ewes/breeding cows, with all progeny sold as stores, plus wintering dairy cows. There has been a significant development/change over the years, including a move away from selling store stock to default position of killing lambs off the ewes which allows the option of selling store stock if needed. A move to a higher cattle ratio (from 80:20 to 60:40) including a reduction in dairy cows wintered and an increase in trading beef animals (bulls), an increase in forage crops grown (fodder beet (*Beta vulgaris subsp vulgaris* L.), kale (*Brassica oleracea* L.), swedes (*B. napus* L.), greenfeed oats (*Avena sativa* L.)) for both winter and summer feed, pasture swards have become more diversified, including cocksfoot, tall fescue, red clover (*T. pratense*), plantain, and chicory, a large area planted into lucerne. In addition, more recently an irrigation development was initiated, with 250 ha now under pivot irrigation. All of which has also seen an increase in stock numbers.

Farm #8. Northland based, originally running a traditional breeding ewe/breeding cow operation, prior to the current owner. The current owner has switched to trading bulls, buying in weaners and selling store as R1-year olds. Most of the weaners are bought in the spring, but the farm is now considering buying in more autumn

weaners to both spread the workload and improve flexibility by delaying purchases until the summer dry was over. Overall, the farmer identified that “*the bulls offer a much more flexible (in the sense they could be readily sold off if the weather turned dry) and profitable system, which is more suited to the climate variability*”.

Farm Systems “Before”

As noted in the pen portraits, all farms originally ran a traditional system with breeding ewes and cows, although one of the Northland farms had gone completely out of sheep in the 1980's, prior to the current farmer taking over. In most cases the farms were selling most of the progeny as store animals, with the remaining small proportion being finished.

Productivity, as reflected in lambing and calving percentages which were generally low (~110-130%/~80%, respectively) as were the carcass weights (CW) of finished animals, e.g. lambs at 13-16 kg CW. This was reflective of much of the sheep and beef industry at the time (Beef + Lamb NZ, 2018-2025, accessed April 2025)

Most of the farmers felt that the farm system was very much at the mercy of the climate, in that if the summer was dry, they were forced to sell stock, often at reduced prices.

How has the climate changed

For all the case study farms, the key climatic challenges they mentioned were a cold/wet winter, and/or dry summers/drought. All the farms reported that the climate is now much more variable, with milder winters and much more variable rainfall. Several of the farms noted that while dry summers were still an issue, often the “drought” was more into the autumn. All also noted that the variability of rainfall also involved heavier downpours occurring more often. These observations are very much in line with those reported (e.g. Jagger 2021; Stevens and Casey 2023). Several commented that the change in the climate means the differences in the seasons are becoming more blurred.

Adaptations

The key motivation for many of the changes was to improve the flexibility of the farm system to cope better with, or respond faster to, climatic change and climatic variability. Commensurate with this was the need to improve financial performance to ensure the farm business remained profitable. When asked which of these two factors – adapting to climate change or financial viability, was the main driver for change, many of the case study farmers responded “both”.

Adaptations to improve climatic resilience, and economic performance, varied between the farms.

Changes at a strategic level included:

- Six had improved subdivision and stock water to improve grazing management
- Six had introduced new pasture species - legumes (particularly sub clover) and more drought and heat tolerant grasses to improve dry matter production and/or survivability over dry periods
- Four had introduced/expanded areas planted in lucerne, again to improve total dry matter production and survivability over dry periods which was grazed rather than harvested for hay. Several commented that, at the time, grazing lucerne with ewes and lambs in spring rather than harvesting, was somewhat revolutionary.
- Two farms had developed irrigation systems

At a more tactical or operational level, changes were:

- All had introduced more flexible management systems, particularly around trading stock, especially

cattle. The key aim here was the ability to reduce stock numbers, even at lighter weights than normal, if an adverse climatic event (e.g. drought) occurred.

- All had improved the productivity of their animals, e.g. higher lambing %, heavier carcass weights
- Some are doing more forage cropping to provide high quality feed/even out the feed supply through dry periods.

Overall, the changes have resulted in a much improved flexibility of their system(s) to cope with climatic uncertainty. They have improved performance where most stock are sold prime, with two farms now running a predominance of bull beef, and one switching to a 100% trading situation of finishing lambs and bulls.

Results

Results of the analysis of the individual farms are summarised in Table 1.

Table 1 Analysis of the Case Study Farms

Farm #1	2014	2023		Farm #2	2009	2024	
Effective area (ha)	758.5	758.5	0%	Effective area (ha)	620	620	0%
Stocking rate (SU/ha)	11.5	11.5	0%	Stocking rate (SU/ha)	9.2	8.8	-4%
Production (kg CW/ha)	258	281	9%	Production (kg CW/ha)	166.8	172.2	3%
Lambing %	133	165	24%	Lambing %	129	145	12%
Breeding ewes (hd)	1,274	823	-35%	Calving %	81	81	0%
Bull beef (hd)	852	1,350	58%	Breeding ewes (hd)	3,300	2,456	-26%
Prime cattle (hd)	83			Breeding cows (hd)	100	92	-8%
GHGs: kg CH ₄ /ha	119.3	120.7	1%	GHGs: kg CH ₄ /ha	89.3	87.5	-2%
N ₂ O as t CO ₂ e/ha	0.74	0.73	-1%	N ₂ O as t CO ₂ e/ha	0.61	0.59	-3%
Total biological GHGs (t CO ₂ e/ha)	4.09	4.12	1%	Total biological GHGs (t CO ₂ e/ha)	3.13	3.05	-3%
Total biological GHGs incorporating forestry offset (t CO ₂ e/ha)		3.27	-21%	Emission intensity (kg CO ₂ e/kg product)	18.8	17.7	-6%
Emission intensity (kg CO ₂ e/kg product)	15.8	14.7	-7%				
Profitability: EBITDA/ha	\$398	\$504	27%	Profitability: EBITDA/ha	153	304	99%

Farm #3	2004	2024		Farm #4	1980	2020	
Effective area (ha)	585	585	0%	Effective area (ha)	400	427	7%
Stocking rate (SU/ha)	9.2	9.2	0%	Stocking rate (SU/ha)	8.0	10.6	33%
Production (kg CW/ha)	183.9	200	9%	Production (kg CW/ha)	148.9	216.6	45%
Lambing %	120	145	21%	Lambing %	119	158	33%
Calving %	82			Calving %	90		
Breeding ewes (hd)	3,000	2,000	-33%	Breeding ewes (hd)	1,291	1,386	7%
Breeding cows (hd)	120			Breeding cows (hd)	90	47	-48%
Trading cattle (hd)		475	100%	Trading cattle (hd)		211	100%
GHGs: kg CH ₄ /ha	88.8	93.8	6%	GHGs: kg CH ₄ /ha	80.0	101.8	27%
N ₂ O as t CO ₂ e/ha	0.56	0.59	5%	N ₂ O as t CO ₂ e/ha	0.5	0.66	32%
Total biological GHGs (t CO ₂ e/ha)	3.04	3.2	5%	Total biological GHGs (t CO ₂ e/ha)	2.73	3.51	29%
				Total Biological GHGs incorporating forestry offset (t CO ₂ e/ha)		-0.47	-113%
Emission intensity (kg CO ₂ e/kg product)	16.7	16.0	-4%	Emission intensity (kg CO ₂ e/kg product)	18.4	16.2	-12%
Profitability: EBITDA/ha	\$54	\$134	148%	Profitability: EBITDA/ha	\$306	\$457	49%

Farm #5	1984	2024		Farm #6	2012	2023	
Effective area (ha)	480	1219	154%	Effective area (ha)	2681	2681	0%
Stocking rate (SU/ha)	9.8	10.2	4%	Stocking rate (SU/ha)	2.4	3.3	38%
Production (kg CW/ha)	181.8	284.8	57%	Production (kg CW/ha)	46.2	67	45%
Lambing %	110	105	-5%	Lambing %	118	140	19%
Calving %	80		-100%	Calving %	94	98	4%
Breeding ewes (hd)	3,000	1,034	-66%	Breeding ewes (hd)	3,645	4,368	20%
Breeding cows (hd)	80		-100%	Breeding cows (hd)	111	130	17%
Trading sheep (hd)		29,351	100%				
Trading cattle (hd)		1,152	100%				
GHGs: kg CH ₄ /ha	95.7	99.3	3.7%	GHGs: kg CH ₄ /ha	23.8	31.8	34%
N ₂ O as t CO ₂ e/ha	0.61	1.08	77%	N ₂ O as t CO ₂ e/ha	0.15	0.2	33%
Total biological GHGs (t CO ₂ e/ha)	3.29	3.85	17%	Total biological GHGs (t CO ₂ e/ha)	0.81	1.09	34%
Emission intensity (kg CO ₂ e/kg product)	18.1	13.5	-25%	Emission intensity (kg CO ₂ e/kg product)	17.6	16.2	-8%
Profitability: EBITDA/ha	\$185	\$927	401%	Profitability: EBITDA/ha	\$141	\$239	70%

Farm #7	2009	2023		Farm #8	2007	2022	
Effective area (ha)	2,945	2,945	0%	Effective area (ha)	340	270	-21%
Stocking rate (SU/ha)	5.8	9.7	67%	Stocking rate (SU/ha)	9.3	12.2	31%
Production (kg CW/ha)	109.1	214.1	96%	Production (kg CW/ha)	231.7	356.2	54%
Lambing %	74	136	84%	Calving %	77		
Calving %	85	95	12%	Breeding cows (hd)	80		
Breeding ewes (hd)	8,776	10,000	14%	Trading cattle (hd)	700	932	100%
Breeding cows (hd)	246	400	63%				
Trading cattle (hd)	2,000	1,994	0%				
GHGs: kg CH ₄ /ha	58.9	96.8	64%	GHGs: kg CH ₄ /ha	99.3	131.4	32%
N ₂ O as t CO ₂ e/ha	0.36	0.63	75%	N ₂ O as t CO ₂ e/ha	0.57	0.92	61%
Total biological GHGs (t CO ₂ e/ha)	2.01	3.34	66%	Total biological GHGs (t CO ₂ e/ha)	3.4	4.6	37%
				Total biological GHGs incorporating forestry offset (t CO ₂ e/ha)		-1.63	-135%
Emission Intensity (kg CO ₂ e/kg product)	18.4	15.6	-15%	Emission intensity (kg CO ₂ e/kg product)	14.5	12.9	-11%
Profitability: EBITDA/ha	\$148	\$386	161%	Profitability: EBITDA/ha	\$279	\$461	65%

Table 1 shows general trends across all farms of:

- An increase in production and productivity indices (e.g. lambing %, carcass weights)
- An increase in profitability
- Either static or increased stocking rates, with only one (Farm #2) reducing their stocking rate.

Table 2 Physical and financial performance averaged across all eight farms.

	Before	After	Change
Stocking rate (SU/ha)	8.2	9.4	16%
Production (kg CW/ha)	166	224	35%
Lambing %	115	142	24%
Calving %	85	91	7%
Breeding ewes (hd)	3,469	3,152	-9%
Breeding cows (hd)	125	112	-10%
Trading cattle (hd)	444	738	66%
Profitability: EBITDA/ha	\$208	\$427	105%

Note that the "before" and "after" period varies for each farm

Table 3 Sheep:Cattle ratios

	Before	After
Farm #1	27:73	14:86
Farm #2	85:15	71:29
Farm #3	83:17	61:39
Farm #4	83:17	69:31
Farm #5	65:35	70:30
Farm #6	83:17	87:13
Farm #7	63:37	57:43
Farm #8	0:100	0:100
Average	61:39	54:46

Table 4 Averaged greenhouse gas emissions

7 farms (that had reduced emission intensity but increased total emissions)	Before	After	Change
Methane (kg CH ₄ /ha)	80.8	96.5	19%
Nitrous oxide (t CO ₂ e/ha)	0.5	0.7	38%
Total biological GHGs (t CO ₂ e/ha)	2.8	3.4	23%
Emission intensity (kg CO ₂ e/kg product) *	17.1	15.0	-12%
All farms (including Farm#2 which had decreased both total emissions and emission intensity)			
Total biological GHGs (t CO ₂ e/ha)	2.8	3.3	19%
Emission intensity (kg CO ₂ e/kg product)	17.3	15.4	-11%

*Includes both meat and wool

Table 3 shows there has also been a general change in stock type: fewer sheep and more cattle, especially trading cattle. This shows that most farms have increased their percentage of cattle, although both Farm#5 and Farm#6 have increased sheep numbers.

Greenhouse Gas Outcomes

Our analysis also investigated the change in GHG emissions, which showed:

- All the case study farms had improved the efficiency of their system, and levels of productivity, which meant that emission intensity, measured as kg CO₂e/kg product (carcass weight + wool) had reduced, varying from -5.3 to -15%.
- Seven of the eight farms had held or increased their stocking rate along with increased production, meaning that total dry matter consumed on-farm had increased and consequently total GHG emissions had increased, varying from +1 to +66%.
- One farm (Farm #2) had decreased their stocking rate, while still improving productivity. This resulted in a decrease in both emission intensity (-5.9%) and total emissions (-2.6%).
- Three of the farms (#1, #4, #8) had planted areas into forestry. If the carbon sequestration by these forests is considered as an offset, they significantly reduce the level of net emissions, to the point where two of the farms (#4, #8) are carbon neutral/positive.

The reduction in emission intensity reflects an improvement in farming efficiency. However, for our international markets, the increase in the total biological emissions is less welcome. This means that farmers may need to take additional actions to reduce total emissions and potentially face a higher carbon levy if one is introduced, given that the proposed levy was based on total biological emissions. In noting this, the actions taken by Farm #2 give some insight as reducing capital stock while improving productivity resulted in a reduction in total emissions.

Constraints faced by the farmers in making changes

The main constraint the farms faced, in making the changes, was finance – for most, any changes and physical development were very largely internally financed from income. Not all farms had kept records of actual costs, but for most, these were in the hundreds of thousands of dollars. All had been active in seeking information and advice, from a range of sources; Beef+Lamb NZ, scientists, other farmers, and consultants.

Discussion

The case study farms reported in this paper provide

insight into the changes in total emissions and emissions intensity reported at a national level. The reduction in total emissions observed nationally has predominantly come from land use change and a reduction in stock numbers as a result. A reduction in total biological emissions was only observed in one of the case study farms (#2). All other farms increased emissions in line with productivity gains. Two farms used forestry as an offset against the increase in overall emissions, which is consistent with the land use change towards forestry that has occurred in the last two decades. The productivity gains seen on all the case study farms are also consistent with the reductions in emissions intensity observed nationally. This gives confidence that the farmers interviewed reflect the broad changes have been happening at that national level.

There were several common themes amongst the interview responses that suggest the case study farmers consider their systems are more resilient to economic and climate pressures, in the sense that their current system is performing well and is more flexible, more profitable, and more climate resilient than the old system. Resilient in the sense that they are more productive and profitable and more flexible in that they can more readily adjust their responses to climatic impacts, such as altering buying/selling time. As such they have confidence in the “new” system going into the future.

Notwithstanding this, all were aware that continuing climate change will mean that they will need to continue to adapt, and the key factor will be in managing climate variability. Several noted that, physical changes apart, there is also an expectation of needing to manage increased and new pest and disease issues, the importance of which was discussed by Mansfield et al. (2021).

Across the geographic spread from Southland to Northland, all the case study farmers reported that they had seen changes in the climate. Their observations noted particularly milder winters, a greater variation in rainfall, and an increased blurring between the seasons. The expectation is that these changes are likely to continue. This, coupled with the ongoing financial pressure that farming is under, will continue to provide an incentive to adapt and adopt.

The results of this study suggest there are a range of proven strategies currently available to farmers wishing to adapt their farm systems to climate change, and they are performing well in maintaining the farm’s resilience to current climatic conditions and variability. The extent to which these adaptations will remain effective over coming decades as the climate changes is uncertain and will be assessed in a subsequent part of the project. The case study farmers commented that

they had frequently benefitted from close involvement of scientists, consultants, and other professionals to assist them in the changes they have made on farm. The changes made required these trusted professionals to work with farmers on an ongoing basis until the system was functioning and the farmers felt they were able to manage the system themselves. The results from this analysis show there is a need for a well-trained professional workforce, armed with the information used on other farms, to enable the widespread adoption of approaches to adapt farm systems to climate change. The success of several reported farmer to scientist engagements (e.g. Avery et al. 2008; Moot et al. 2024) provides a template for independent extension that can lead to significant changes in farm practices, profitability and environmental outcomes.

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