BRIEF COMMUNICATION: Potential alterations in New Zealand sheep, beef cattle and deer numbers due to climate change: what can genetics offer?

KM McRae[a]*, S Rowe[a], and JC McEwan[a]

[a]*AgResearch Invermay, Private Bag 50034, Mosgiel. 9053, New Zealand*

**Corresponding author.* Email: kathryn.mcrae@agresearch.co.nz

Abstract

Many producers of red meat in New Zealand run enterprises consisting of a mix of sheep, beef cattle and deer, with obvious differences in species ratios across regions when aggregated. The aim of this study was to use these regional species ratios to predict livestock number changes in New Zealand in response to climate change. Simple linear regression was performed using mean temperature and species ratio (sheep, beef cattle and deer) for each region. The slopes of these linear equations were used to estimate "business-as-usual" for each region in year 2100 under different models of climate change. An overall decrease in sheep and deer numbers by up to 38% and 75%, respectively, is predicted, along with an increase in beef cattle numbers by up to 60%. Genetics provides an opportunity to select for animals that are adapted to the changing environment through reproductive plasticity, disease resistance, and heat tolerance, and therefore to moderate these predicted changes.

Keywords: climate change; genetics; sheep; beef cattle; deer

Introduction

Many producers of red meat in New Zealand run mixed enterprises consisting of several species. Mixed enterprises are managed to optimise financial return, and in order to do this the proportion of livestock classes (sheep, beef cattle and deer) on farm can be varied to suit economic conditions and preferences (Joyce 1970; Morris 2013). This is not only a result of the financial return from each individual species, but an adjustment made to maximise return across the entire farm system. Integration of factors such as growth and quality of pasture across seasons is required, as well as minimising disease challenges including external and internal parasites, and fungal toxins such as sporidesmin and zearalenone. Each farmer makes an individual decision for his farm, but when aggregated there are obvious differences in species ratios between the various New Zealand regions, which are broadly reflective of climatic differences. Essentially, these ratios are equivalent to the results from a forecasting or prediction market and this is commonly known as the "wisdom of the crowds". Such markets have been demonstrated repeatedly to provide near-optimal solutions (Surowiecki 2004).

Several models of climate change have predicted temperature and rainfall values by 2100 across New Zealand. An obvious tactic for producers to adapt to climatic changes is to change livestock classes on-farm to adapt to changes in growth and quality of pasture, and disease challenges. The aim of this study was to use regional proportions of sheep, beef cattle and deer to predict changes in livestock numbers in response to climate change in New Zealand, and discuss the opportunities for the use of genetics.

Materials and methods

Using different emission scenarios and model climate sensitivities, mean New Zealand temperatures are projected to increase by 0.7–3.1°C, by 2081–2100 relative to 1986–2005 (Ministry for the Environment 2016). The four scenarios, known as representative concentration pathways (RCPs), include one mitigation pathway (RCP2.6, which requires removal of some of the CO_2 presently in the atmosphere), two stabilisation pathways (RCP4.5 and RCP6.0) and one pathway with very high concentrations of greenhouse gasses (RCP8.5).

Livestock numbers by region for sheep, deer, beef and dairy cattle were obtained from Statistics New Zealand and are shown in Table 1. The assumption was made that this was a 'business-as-usual' prediction within farms producing red meat, i.e., they would change livestock species composition, but not land use enterprise, such as dairy, forestry, horticultural or arable farming. Assumptions for the 2100 scenario were as follows: 1) dairy cattle numbers were assumed to stay as a fixed proportion of SU numbers, 2) sheep, beef and deer farms will stay the same, however, stock unit (SU) proportions for each species will be redistributed, 3) as the temperature rises, shifts in sheep/beef/deer SU proportions reflect the environmental changes.

The percentage of sheep, beef or deer as a proportion of total stock units in each region was calculated as follows:

$$\%x = \frac{SUx}{1s + 5.5b + 1.9d}$$

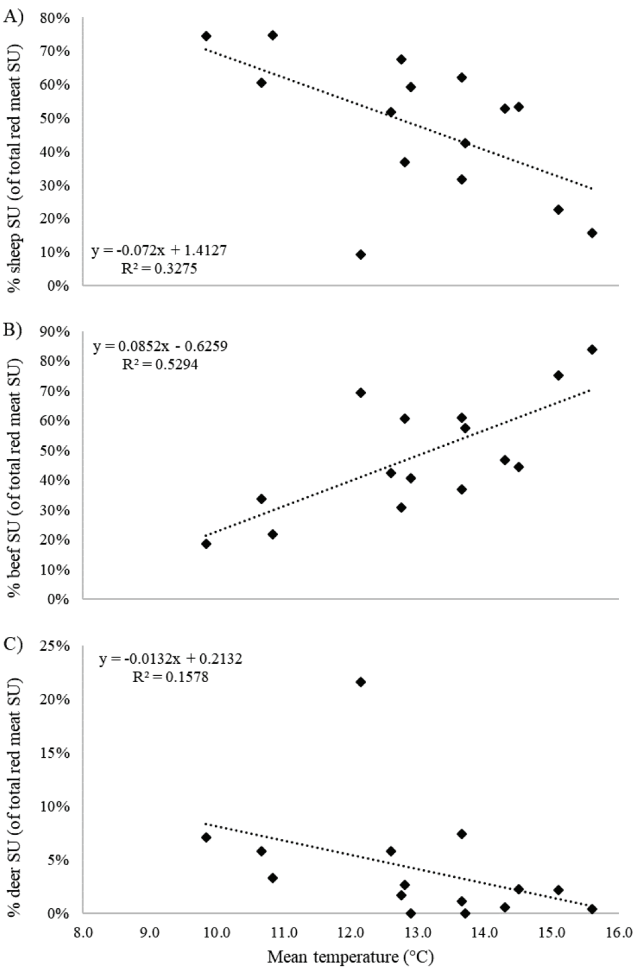
Where s, b and d represent the number of sheep, beef cattle and deer respectively. For the purposes of this study, sheep were defined as 1 SU, beef cattle 5.5 SU, dairy cattle 8.5 SU, and deer 1.9 SU (Beef + Lamb New Zealand Economic Service). This was calculated for each species in each region. Simple linear regression was performed using the current mean regional temperature and species composition. Linear equations were produced with percentage of each species as the response variable, and mean regional temperature as the predictor. The slopes of these equations were then used to predict species composition for each region with predicted mean

Table 1 Livestock numbers and total red-meat stock units by regional council, as at 30 June 2016 (Statistics New Zealand).

	Livestock numbers by regional council[1]				
Region	Sheep	Beef	Dairy	Deer	Red-meat stock units[2]
Northland	366,197	356,823	404,415	4,824	2,337,889
Auckland	202,200	121,690	165,417	10,124	890,731
Waikato	1,666,388	498,662	1,855,170	63,811	4,530,270
Bay of Plenty	263,380	92,583	339,170	32,580	834,489
Gisborne	1,515,181	243,273	11,950	8,358	2,869,063
Hawkes Bay	2,872,524	434,837	90,854	63,862	5,385,465
Taranaki	434,333	106,619	555,532	0	1,020,738
Manawatu-Wanganui	5,040,174	543,526	524,295	47,158	8,119,167
Wellington	1,333,163	110,801	110,543	17,772	1,976,335
Tasman-Nelson	257,878	38,334	63,310	15,245	497,681
Marlborough	434,222	54,063	25,148	0	731,569
West Coast	23,148	31,902	180,956	28,825	253,377
Canterbury	4,584,936	465,462	1,271,057	232,947	7,587,576
Otago	4,818,842	256,178	312,087	112,240	6,441,077
Southland	3,711,484	169,251	708,895	185,664	4,995,126

[1]Numbers as at 30 June 2016. [2]Red-meat stock units (SU) were calculated by adding sheep, beef cattle and deer SU in each region. Sheep were defined as 1 SU, beef cattle 5.5 SU, dairy cattle 8.5 SU, and deer 1.9 SU (Beef + Lamb New Zealand Economic Service).

Figure 1 Percentage of sheep (A), beef cattle (B) and deer (C) as a proportion of total stock units (SU) in each region plotted against mean regional temperature (°C).



temperatures for each RCP scenario (Table 2).

If the predicted percentage was less than zero, the estimate was set to zero and the percentage of positive estimates adjusted proportionally to their estimates. Predicted livestock numbers were then back-calculated using species composition and sheep/beef/deer stock unit numbers for each region, and percentage change compared to current numbers estimated. The slopes were used rather than the equations themselves, as it was assumed that the regional deviations from the equations reflected optimisation of enterprises to environmental variables not captured by mean temperature, such as precipitation and pasture-growth curves. Note that this method also assumes no change in pasture growth, however, as the emphasis here is on species composition this is unlikely to change the overall results dramatically.

Results and discussion

Simple linear regression indicated that there was a low to moderate correlation between species proportion and mean regional temperature (Figure 1A-C). Using the slopes from these equations, we predicted a national decline in sheep numbers, ranging from 9 to 38% (Table 3). Beef cattle numbers are predicted to rise between 14% and 60%. Deer numbers are also predicted to fall by between 25% and 75%.

Notwithstanding the obvious limitations of this study, this analysis indicates that climate change is likely to have marked effects on species composition on New Zealand farms producing red meat, and the implications of this need to be included in any prediction scenario. This estimate of the directional change in proportions of livestock class indicates that under all predicted future climate scenarios, from a mitigation pathway through to a pathway with high concentrations of greenhouse gasses, beef cattle numbers will increase and sheep and deer numbers will decrease. Currently, 71% of beef cattle are located in the North Island of New Zealand, where they play an important role in controlling pasture growth and quality, especially in areas

Table 2 Predicted species composition ratios (2 decimal places) for each region, based on predicted mean temperatures under different models of climate change. The four models, known as representative concentration pathways (RCPs), include one mitigation pathway (RCP2.6), two stabilisation pathways (RCP4.5 and RCP6.0) and one pathway with very high greenhouse gas concentrations (RCP8.5).

	Current		RCP2.6		RCP4.5		RCP6.0		RCP8.5	
Region	Mean temp (°C)	Sheep Beef Deer	Mean temp (°C)	Sheep Beef Deer	Mean temp (°C)	Sheep Beef Deer	Mean temp (°C)	Sheep Beef Deer	Mean temp (°C)	Sheep Beef Deer
Northland	15.6	0.16	16.3	0.11	17.0	0.06	17.5	0.02	18.7	0.00
		0.84		0.89		0.94		0.98		1.00
		0.00		0.00		0.00		0.00		0.00
Auckland	15.1	0.23	15.8	0.18	16.5	0.13	17.0	0.09	18.2	0.00
		0.75		0.81		0.87		0.91		1.00
		0.02		0.01		0.00		0.00		0.00
Waikato	12.8	0.37	13.5	0.32	14.2	0.27	14.7	0.23	15.9	0.14
		0.61		0.67		0.72		0.77		0.86
		0.03		0.02		0.01		0.00		0.00
Bay of Plenty	13.7	0.32	14.4	0.27	15.1	0.21	15.6	0.18	16.8	0.09
		0.61		0.67		0.73		0.77		0.87
		0.07		0.06		0.06		0.05		0.03
Gisborne	14.3	0.53	15.0	0.48	15.7	0.42	16.2	0.38	17.4	0.29
		0.47		0.52		0.58		0.62		0.71
		0.01		0.00		0.00		0.00		0.00
Hawkes Bay	14.5	0.53	15.2	0.48	15.9	0.43	16.3	0.40	17.6	0.30
		0.44		0.5		0.56		0.60		0.70
		0.02		0.01		0.00		0.00		0.00
Taranaki	13.7	0.43	14.4	0.37	15.1	0.32	15.5	0.29	16.8	0.19
		0.57		0.63		0.68		0.71		0.81
		0.00		0.00		0.00		0.00		0.00
Manawatu-Wanganui	13.7	0.62	14.4	0.57	15.1	0.52	15.5	0.49	16.8	0.39
		0.37		0.43		0.48		0.51		0.61
		0.01		0.00		0.00		0.00		0.00
Wellington	12.8	0.67	13.5	0.62	14.2	0.57	14.6	0.54	15.8	0.45
		0.31		0.37		0.43		0.46		0.55
		0.02		0.01		0.00		0.00		0.00
Tasman-Nelson	12.6	0.52	13.2	0.47	14.0	0.42	14.4	0.39	15.6	0.30
		0.42		0.47		0.54		0.58		0.68
		0.06		0.05		0.04		0.03		0.02
Marlborough	12.9	0.59	13.6	0.54	14.3	0.48	14.7	0.45	15.9	0.36
		0.41		0.46		0.52		0.55		0.64
		0.00		0.00		0.00		0.00		0.00
West Coast	12.2	0.09	12.8	0.05	13.6	0.00	13.9	0.00	15.2	0.00
		0.69		0.74		0.80		0.81		0.84
		0.22		0.21		0.20		0.19		0.16
Canterbury	10.7	0.60	11.4	0.55	12.1	0.50	12.5	0.47	13.7	0.39
		0.34		0.40		0.46		0.49		0.59
		0.06		0.05		0.04		0.03		0.02
Otago	10.8	0.75	11.4	0.70	12.1	0.65	12.4	0.63	13.6	0.54
		0.22		0.27		0.33		0.36		0.46
		0.03		0.03		0.02		0.01		0.00
Southland	9.8	0.74	10.4	0.70	11.1	0.65	11.4	0.63	12.6	0.54
		0.19		0.24		0.30		0.32		0.42
		0.07		0.06		0.05		0.05		0.03

that are not accessible to traditional cultivation techniques (McCall 1994). Similarly, sheep face elevated disease challenges in regions with warmer temperatures, including the pathogenic gastrointestinal nematode, *Haemonchus contortus*, external parasite challenge, including flystrike, and fungal toxins including sporidesmin and zearalenone. Similar comments apply to deer, as they also have a greater susceptibility to ticks than cattle. This makes cattle percentage in the enterprise a key parameter in managing these disease risks as temperature increases. Additionally, compared to cattle, both deer and most New Zealand sheep breeds have longer anoestrus, thereby limiting their range

Table 3 Predicted changes in livestock species numbers in 2100 based on different models of climate change. The four models, known as representative concentration pathways (RCPs), include one mitigation pathway (RCP2.6), two stabilisation pathways (RCP4.5 and RCP6.0) and one pathway with very high greenhouse gas concentrations (RCP8.5).

	Sheep	Beef	Deer
Current	27,524,050	3,524,004	823,410
RCP2.6	25,155,366	4,026,042	616,819
% change	-9%	14%	-25%
RCP4.5	22,660,081	4,538,244	447,437
% change	-18%	29%	-46%
RCP6.0	21,236,541	4,824,339	368,496
% change	-23%	37%	-55%
RCP8.5	17,004,142	5,650,791	203,716
% change	-38%	60%	-75%

of potential mating and birthing dates as well as optimal fecundity levels in order to best match pasture growth curves. As such, genetic adaptation in these species needs to address these issues.

Increased mean annual temperatures are predicted to improve autumn and winter pasture growth (Baars et al 1990). This provides opportunities to exploit pasture availability by developing earlier lambing and calving systems. There is genetic variability for reproductive seasonality in both sheep (Al-Shorepy & Notter 1997), and deer (Asher et al. 2000), suggesting that genetic selection can be used as a tool to improve fertility in these systems, although progress may be slow and will require appropriate trait recording.

Long-term climate change predictions suggest that the risk of disease such as facial eczema (FE) will increase nationally (Dennis et al 2014). Sheep are more susceptible to FE than are cattle, as they graze more closely to the base of the sword. Diseases such as haemonchosis and pneumonia are also more prominent in sheep in the North Island of New Zealand (Lawrence et al. 2007; Alley 2002; Goodwin et al. 2004). There is well-documented evidence for between-animal variation in the ability of livestock to resist multiple infectious diseases, including infection with internal parasites (Morris et al. 1997; Morris et al. 2003), pneumonia (Snowder 2009; McRae et al. 2016), flystrike (Pickering et al. 2012) and facial eczema (Morris et al. 1990; Morris et al. 1995). These differences mean that the approach to manage increased animal health challenges can include genetic selection for enhanced resistance. This can be used as a complementary tool to current methods for disease control.

There is a growing interest in the ability of livestock to adapt to climate differences and to tolerate heat stress. The genetic ability to adapt to climate change is important not only for resistance to disease, but also tolerance to thermal stress (Rojas-Downing et al. 2017). Genetic variation in the response to heat stress has been identified in several livestock species, both between-breeds (Paula-Lopes et al. 2003; Romero et al. 2013) and within-breeds (Mackinnon et al. 1991; Ravagnolo & Misztal 2000). The value of genomic selection as a tool for breeding for heat tolerance has been reported in dairy cattle (Garner et al. 2016). Additionally, in conjunction with existing genetic and genomic tools, new tools such as methylation assays can estimate level of stress an individual has been exposed to during its lifetime (Murgatroyd et al. 2009). These tools can be used to predict longevity, and can help to identify individuals that are genetically better adapted to their environment.

In summary, climate change is likely to have a marked impact on the species composition on farms producing red meat in New Zealand. Increases in mean temperature and rainfall will result in breed or even species replacement, with beef cattle numbers likely to increase, to the detriment of sheep and deer numbers. Genetics provides an opportunity to select for animals that are better adapted to the changing environment, through reproductive plasticity, disease resistance, and heat tolerance. These changes need to be appropriately reflected in breeding scheme indices for all three species.

References

Al-Shorepy SA, Notter DR 1997. Response to selection for fertility in a fall-lambing sheep flock. Journal of Animal Science 75(8): 2033-2040.

Alley MR 2002. Pneumonia in sheep in New Zealand: an overview. New Zealand Veterinary Journal 50: 99–101.

Asher GW, O'Neill KT, Scott IC, Mockett BG, Fisher MW 2000. Genetic influences on reproduction of female red deer (*Cervus elaphus*):(1) seasonal luteal cyclicity. Animal Reproduction Science 59(1-2): 43-59.

Baars, JA, Radcliffe JE, Rollo MD 1990. Climatic change effects on seasonal patterns of pasture production in New Zealand. Proceedings of the New Zealand Grassland Association 51: 43-46.

Dennis NA, Amer PR, Meier S 2014. BRIEF COMMUNICATION: Predicting the impact of climate change on the risk of facial eczema outbreaks throughout New Zealand. Proceedings of the New Zealand Society of Animal Production 74: 1-6.

Garner JB, Douglas ML, Williams SO, Wales WJ, Marett LC, Nguyen TT, Reich CM, Hayes BJ 2016. Genomic selection improves heat tolerance in dairy cattle. Scientific Reports 6: 34114.

Goodwin KA, Jackson R, Brown C, Davies PR, Morris RS, Perkins NR, 2004. Pneumonic lesions in lambs in New Zealand: patterns of prevalence and effects on production. New Zealand Veterinary Journal 52: 175–179.

Joyce, JP 1970. Intensive beef and sheep production. Proceedings of the New Zealand Grassland Association 32: 168-180.

Lawrence KE, Leathwick DM, Rhodes AP, Jackson R, Heuer C, Pomroy WE, West DM, Waghorn TS, Moffat JR 2007. Management of gastrointestinal nematode parasites on sheep farms in New Zealand. New Zealand Veterinary Journal 55(5): 228-234.

Mackinnon MJ, Meyer K, Hetzel DJ 1991. Genetic variation and covariation for growth, parasite resistance and heat tolerance in tropical cattle. Livestock Production Science 27(2-3): 105-122.

McCall DG 1994: The complementary contribution of the beef cow to other livestock enterprises. Proceedings of the New Zealand Society of Animal Production 54: 323-327.

McRae KM, Baird HJ, Dodds KG, Bixley MJ, Clarke SM 2016. Incidence and heritability of ovine pneumonia, and the relationship with production traits in New Zealand sheep. Small Ruminant Research 145: 136-141.

Ministry for the Environment 2016. Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment. Wellington: Ministry for the Environment.

Morris CA, Towers NR, Tempero HJ, Cox NR, Henderson HV 1990. Facial eczema in Jersey cattle: heritability and correlation with production. Proceedings of the New Zealand Society of Animal Production 50: 255-259.

Morris CA, Towers NR, Wheeler M, Wesselink C 1995. Selection for or against facial eczema susceptibility in Romney sheep, as monitored by serum concentrations of a liver enzyme. New Zealand Journal of Agricultural Research 38: 211-219.

Morris CA, Vlassoff A, Bisset SA, Baker RL, West CJ, Hurford AP 1997. Responses of Romney sheep to selection for resistance or susceptibility to nematode infection. Animal Science 64(2): 319-329.

Morris CA, Green RS, Cullen NG, Hickey SM 2003. Genetic and phenotypic relationships among faecal egg count, anti-nematode antibody level and live weight in Angus cattle. Animal Science 76: 167–174.

Morris ST 2013. Sheep and beef cattle production systems. In: Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand. Pg 79-84.

Murgatroyd C, Patchev AV, Wu Y, Micale V, Bockmühl Y, Fischer D, Holsboer F, Wotjak CT, Almeida OF, Spengler D 2009. Dynamic DNA methylation programs persistent adverse effects of early-life stress. Nature neuroscience 12(12): 1559-1566.

Paula-Lopes FF, Chase CC, Al-Katanani YM, Krininger CE, Rivera RM, Tekin S, Majewski AC, Ocon OM, Olson TA, Hansen PJ 2003. Genetic divergence in cellular resistance to heat shock in cattle: differences between breeds developed in temperate versus hot climates in responses of preimplantation embryos, reproductive tract tissues and lymphocytes to increased culture temperatures. Reproduction 125(2): 285-294.

Pickering NK, Dodds KG, Blair HT, Hickson RE, Johnson PL, McEwan JC 2012. Genetic parameters for production traits in New Zealand dual-purpose sheep, with an emphasis on dagginess. Journal of Animal Science 90: 1411-1420.

Ravagnolo O, Misztal I 2000. Genetic component of heat stress in dairy cattle, parameter estimation. Journal of Dairy Science 83(9): 2126-2130.

Rojas-Downing MM, Nejadhashemi AP, Harrigan T, Woznicki SA 2017. Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management 16: 145-163.

Romero RD, Pardo AM, Montaldo HH, Rodríguez AD, Cerón JH 2013. Differences in body temperature, cell viability, and HSP-70 concentrations between Pelibuey and Suffolk sheep under heat stress. Tropical Animal Health and Production 45(8): 1691-1696.

Snowder G 2009. Genetics, environment and bovine respiratory disease. Animal Health Research Reviews 10(02): 117-119.

Surowiecki J 2004. The Wisdom of Crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies and nations. New York: Doubleday. 296 p.