

Supplementary Data

Liveweight data by animal classes, energy equations for feed budgeting, herbage metabolizable energy, and pasture growth, pasture balance and annual pasture growth index associated with New Zealand southern North Island (Class IV, medium slope) Sheep and Beef Cattle Production Systems from the 1980s to 2010-11.

Evolution in Configuration and Productivity of New Zealand Hill Country Sheep and Beef Cattle Systems

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Table S1

Liveweights by stock classes used in the model for the calculation of energy requirements of animals in New Zealand North Island (Class IV) sheep and beef cattle production systems in the 1980s and 2010–11^a.

Stock classes	kg per head											
	J	A	S	O	N	D	J	F	M	A	M	J
MA ewe	52 (55)	53 (56)	55 (58)	56 (59)	56 (59)	57 (60)	59 (62)	60 (63)	59 (62)	59 (62)	60 (63)	55 (58)
2-tooth ewe	48 (50)	49 (51)	51 (53)	54 (56)	56 (58)	58 (60)	59 (61)	60 (62)	59 (61)	59 (61)	60 (62)	55 (57)
Wet hogget	42 (43)	43 (44)	46 (47)	49 (50)	51 (52)	52 (53)	55 (56)	56 (57)	56 (57)	56 (57)	56 (57)	55 (56)
Dry hogget	36 (37)	37 (38)	41 (42)	44 (45)	47 (48)	52 (53)	55 (56)	56 (57)	56 (57)	56 (57)	56 (57)	55 (56)
Lamb (replacement)	0.66	3.12	5	9	13	17	23	25	28	30	32	34
Lamb (finishing)	0.66	3.12	5 (6)	9 (15)	13 (23)	17 (27)	23 (33)	25 (35)	28 (38)	30 (40)	32 (42)	34 (44)
Foetus	0.66	3.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.07
Wether or Ram lamb	0.66	3.12	5 (6)	9 (15)	13 (23)	17 (27)	23 (33)	29 (39)	35 (45)	38 (48)	40 (51)	41 (51)
Wether or Ram hogget	43 (45)	45 (47)	46 (48)	47 (49)	51 (53)	55 (57)	59 (61)	60 (62)	61 (63)	63 (65)	65 (67)	66 (68)
Wether or Ram	65 (68)	65 (68)	65 (68)	66 (69)	66 (69)	67 (70)	69 (72)	70 (73)	70 (73)	70 (73)	71 (74)	71 (74)
Heifer calf				34	48	59	80	130	175	179	193	208
R1–R2yr heifer	223	237	252	266	281	296	310	325	339	354	369	383
R2–R3yr heifer	392	376	354	331	340	354	389	408	408	415	422	430
Beef cow	435	454	472	488	504	520	529	537	515	515	515	515
Steer calf				35 (46)	52 (80)	69 (97)	85 (113)	101 (129)	118 (146)	134 (146)	150 (162)	178 (178)
R1–R2yr steer	207 (235)	225 (253)	247 (275)	270 (298)	294 (322)	318 (346)	351 (379)	381 (409)	372 (400)	363 (391)	354 (382)	368 (396)
R2–R3yr steer	362 (390)	383 (411)	388 (416)	450 (478)	482 (510)	514 (542)	533 (561)	529 (557)	525 (553)	522 (550)	552 (580)	582 (610)
Steer	612 (640)	621 (649)	631 (659)	640 (668)								
Bull calf				30	52	73	95	121	147	171	182	192
R1–R2yr bull	200	224	228	228	265	314	364	381	398	415	432	449
R2–R3yr bull	466	483	500	517	534	551	568	582	612	621	631	640
Bull	640	640	640	640	640	640	640	640	640	640	640	640

^a In parentheses – included only if different from that in the 1970s and 1980s, as suggested by the owner of Farm B. **Sheep:** Foetus to lamb birth for single lamb (Koong et al., 1975). Wet hogget and replacement (Baker et al., 1979). Lamb at birth to weaning, dry hogget, replacement hogget, 2-tooth ewe, and Mixed Age (MA) ewe (Parker, 1986; Geenty, 1979). Wether and Ram; 3–16 months (Baker et al., 1979). Adult ram or wether is assumed to be 10 kg heavier than a MA ewe of similar age. **Cattle:** Steer or bull calf at birth to weaning (Everitt et al., 1980). R1–R3yr steers (Barton, 1975). Heifer calf at birth to weaning and R2yr–R3yr heifers (Anderson et al., 1981). R3yr heifer and beef cows (Nicoll, 1979). Bull calf to 15–20 months old (McRae, 1985; McRae, 1987). Bull of 20–32 months old (Farm A's 1985/86 record). R3yr steer and much older bull (Farm A's 1999/00 record). Liveweight data are rounded to nearest values and are omitted from the table if they are not applicable in the model. Information was verified again by the farmers of Farms A and B before use. **Sources:** Anderson, W.J., Pleasants, A.B., Barton, R.A. (1981). Effect of plane of nutrition on calf birth weight, calf growth rate, and subsequent performance of Angus heifers calving in the spring. *New Zealand Journal of Agricultural Research* 24: 269–275.; Baker, R.L., Clarke, J.N., Carter, A.H., Diprose, G.D. (1979). Genetic and phenotypic parameters in New Zealand Romney sheep. *New Zealand Journal of Agricultural Research* 22: 9–21.; Barton, R.A. (1975). The growth and carcass characteristics of Angus, Red Poll, Friesian, and Jersey steers – Trial IX (P. 41–49). *Sheepfarming Annual 1975*. Massey University, Palmerston North, New Zealand.; Everitt, G.C., Jury, K.E., Dalton, D.C., Langridge, M. (1980). IV. Growth and carcass composition of straight-bred and beef-cross Friesian steers in several environments. *New Zealand Journal of Agricultural Research* 23: 11–20.; Geenty, K.G. (1979). Lactation performance, growth, and carcass composition of sheep. *New Zealand Journal of Agricultural Research* 22(2): 241–250.; Koong, L.J., Garrett, W.N., Ratray P.V. (1975). A description of the dynamics of fetal growth in sheep. *Journal of Animal Science* 41: 1065–1068.; McRae, A.F. (1985). *Tuapaka Beef Farm: The First Two Seasons*. Tuapaka Farm Series Publication No. 2, Massey University, New Zealand.; Nicoll, G.B. (1979). Influence of pre- and post-calving pasture allowance on hill country beef cow and calf performance. *New Zealand Journal of Agricultural Research* 22: 417–424.

Table S2

Energy equations and constants used in the Excel MEB model to calculate energy requirements of animals in New Zealand North Island (Class IV) sheep and beef cattle production systems.

Energy requirement	Equation	Description and note
Total energy requirements (MJ d ⁻¹)	ME _M +ME _{G+} +ME _G +ME _P +ME _L	General equations. Energy requirement for grazing activity is accounted for using the metabolic coefficient = <i>a</i> . <i>a</i> = 0.52 (sheep) <i>a</i> = 0.56 (breeding ram) <i>a</i> = 0.66 (cattle) <i>b</i> = 55 (sheep) <i>b</i> = 55 (cattle, except for adult bulls or steers) <i>b</i> = 70 (adult bulls or steers) <i>c</i> = 20 (sheep) <i>c</i> = 25 (cattle, except adult bulls or steers) <i>c</i> = 40 (adult bulls or steers)
ME _M : Body maintenance (MJ d ⁻¹)	<i>a</i> × liveweight ^{0.75}	
ME _{G+:} Gaining weight (MJ d ⁻¹)	<i>b</i> × liveweight gained (kg d ⁻¹)	
ME _{G-:} Losing weight (MJ d ⁻¹)	<i>c</i> × liveweight lost (kg d ⁻¹)	
ME _{P:} Pregnancy (MJ d ⁻¹)	Sheep: ME _M +ME _{G+} of sheep foetus. Equation for foetus growth is as follows (Koong et al., 1975, as cited in Table S1): $W = 0.000103e^{0.613N + (0.128 - 0.00038T)T}$	W = Liveweight N = Number of foetus T = Day of pregnancy
ME _{L:} Lactation (MJ d ⁻¹)	Cattle: 4.6, 12.3, 21.8, 37.4 and 23.4 MJ ME hd ⁻¹ d ⁻¹ . ME _M +ME _G of lamb and calf until weaning.	Fixed at those amounts for the last five months of pregnancy. <i>a</i> = 0.45 (female lamb), 0.50 (male lamb) <i>a</i> = 0.65 (female calf), 0.72 (male calf) <i>b</i> = as in Table 5 (lamb) and Table 12 (calf) of Nicol and Brookes (2007).

Table S3

Herbage metabolisable energy content used in the Excel MEB model for the calculation of energy requirements of animals in New Zealand North Island (Class IV) sheep and beef cattle production systems.

Stock	MJ ME kg DM ⁻¹												\bar{x}
	J	A	S	O	N	D	J	F	M	A	M	J	
Sheep ^a	11.1	11.4	11.7	11.4	11.0	10.2	9.4	9.3	9.3	10.4	10.7	10.9	10.5
Sheep ^b	11.8	11.2	10.8	11.0	10.7	10.7	10.2	10.7	11.5	11.6	12.0	12.2	11.2
Cattle	9.67	10.10	9.83	10.52	10.19	8.92	7.79	7.53	7.83	8.05	8.36	9.17	8.95
Cattle	10.30	9.91	9.07	10.15	9.94	9.41	8.46	8.61	9.68	8.98	9.37	10.30	9.51
% ^c	12.9	11.5	16.0	7.7	7.1	12.1	17.1	19.5	15.8	22.6	21.9	15.9	15.0

^a McRae (1987).

^b Machado et al. (2005).

^c ME of herbage for finishing cattle was reduced at this percentage.

Table S4

Mean precipitation (P, mm) and temperature (°C) data used in the modelling of herbage supply using GROW.

Year	System/ Farms	Month (Precipitation/ Temperature)												Annual
		J	A	S	O	N	D	J	F	M	A	M	J	
1980–81	B (P)	69	236	79	18	119	200	21	80	60	189	160	171	1602
	C (P)	172	156	138	130	121	148	90	67	113	122	145	158	1560
	AS (P)	103	112	109	75	115	117	66	69	97	120	98	168	1249
	B (°C)	7.3	8.2	11.0	12.4	12.5	15.1	18.5	17.6	17.8	14.2	9.3	9.6	12.8
	C (°C)	7.3	8.3	10.6	11.8	14.1	15.9	17.7	17.1	16.6	13.3	10.3	7.8	12.6
	AS (°C)	9.4	9.9	12.4	14.3	14.7	16.8	19.4	19.1	18.9	15.8	11.9	11.2	14.5
1985–86	A (P)	481	70	59	128	124	170	119	142	61	44	65	48	1511
	B (P)	297	0	115	177	0	170	305	4.3	167	0	367	260	1862
	C (P)	125	85	68	78	113	118	74	117	186	17	44	69	1094
	AS (P)	153	97	87	65	110	133	162	135	59	87	102	97	1287
	A (°C)	9.0	8.1	10.3	10.9	13.1	16.8	18.8	17.6	14.7	13.5	10.1	8.4	12.6
	B (°C)	8.0	6.7	9.3	10.0	13.2	16.4	19.1	17.1	14.7	12.8	9.3	7.3	12.0
	C (°C)	8.6	7.9	10.3	10.9	13.1	17.0	19.5	18.9	15.6	13.1	10.5	8.2	12.8
	AS (°C)	10.7	9.7	12.1	12.4	14.8	17.9	19.9	18.9	17.0	15.2	12.5	10	14.3
1992–93	B (P)	325	73	191	240	74	106	45	209	93	58	0	0	1739
	AS (P)	187	175	149	145	89	148	59	86	117	71	118	168	1512
	B (°C)	13.8	8.1	9.1	11	14	14.1	14.8	15	13.5	12.2	10.3	9.9	12.2
	AS (°C)	9.6	9.1	9.7	11.9	15.1	16.2	16.9	16.8	15.3	12.8	11.5	10.4	12.9
1999–00	A (P)	110	44	40	61	222	26	146	27	93	115	83	67	1034
	B (P)	129	74	50	48	252	52	128	42	100	87	123	66	1151
	AS (P)	120	99	88	84	186	73	106	33	60	153	122	116	1240
	A (°C)	8.5	7.7	10.6	13.5	14.9	14.6	16.7	17.1	15.3	13.7	11.3	8.7	12.7
	B (°C)	8.4	7.6	10.8	13	14.8	14.6	16.7	17.1	15.0	14.0	11.1	8.9	12.7
	AS (°C)	9.8	9.3	11.6	13.9	15.5	15.8	17.6	18.2	16.4	15.0	12.7	10.5	13.9
2003–04	A (P)	64	278	261	69	87	72	285	316	46	46	108	94	1726
	B (P)	82	211	266	90	151	61	238	396	53	90	90	136	1864
	AS (P)	70	98	163	139	85	100	103	256	15	67	184	146	1426
	A (°C)	7.8	8.9	11.1	11.2	12.5	16.5	18.6	16.4	14.6	12.5	10.7	9.8	12.6
	B (°C)	6.3	8.6	10.3	11.2	12.3	15.6	18.4	16.2	14.5	11.6	11.2	9.8	12.2
	AS (°C)	8.9	10.4	12.6	12.7	14.4	17.8	19.3	17.8	15.6	18.6	13.2	11.2	14.4
2010–11	A (P)	150	105	182	136	31	52	170	15	149	167	38	92	1287
	B (P)	183	158	192	90	13	47	155	23	127	174	73	113	1348
	C (P)	86	127	138	62	3	36	112	12	113	121	50	67	927
	AS (P)	123	102	92	92	80	89	72	76	85	88	99	116	1114
	A (°C)	7.1	9.7	11.2	11.7	14.6	17.8	18.0	19.2	15.8	12.6	12.7	9.8	13.4
	B (°C)	7.3	9.7	11.1	11.6	13.8	17.3	17.3	18.5	15.1	12.2	12.6	9.7	13.0
	C (°C)	6.8	9.7	11.2	11.1	14.6	18.1	18.3	19.2	15.7	12.0	12.4	9.1	13.2
	AS (°C)	9.4	10	11.6	13.2	14.9	17	18.5	18.7	17.1	14.6	12.3	10.1	13.9

A, B and C = Case-study Farms A, B and C. AS = Average System (B+LNZ Class IV, medium slope, New Zealand southern North Island hill country sheep and beef cattle production systems).

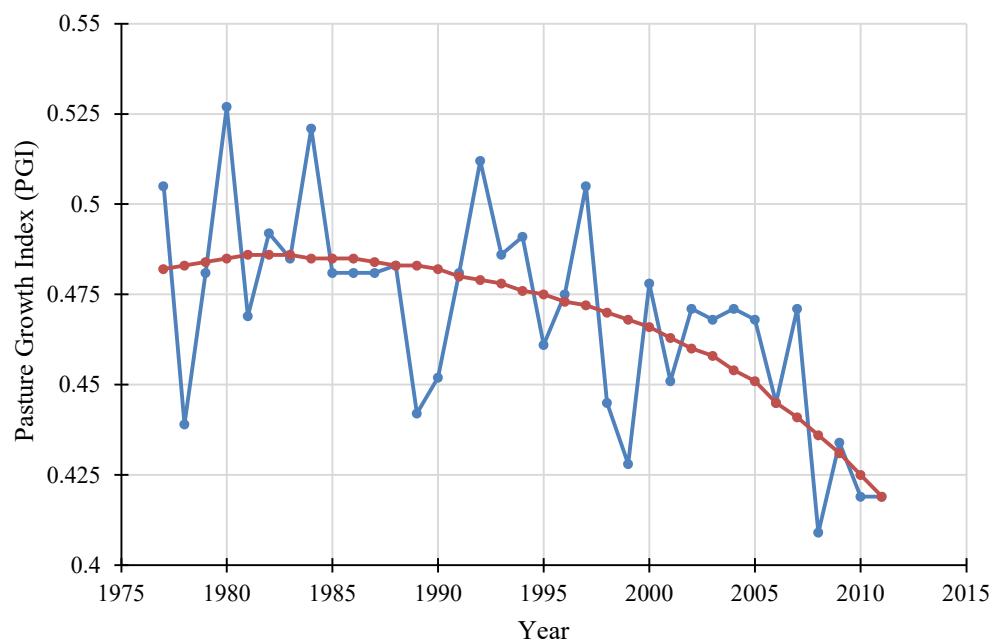
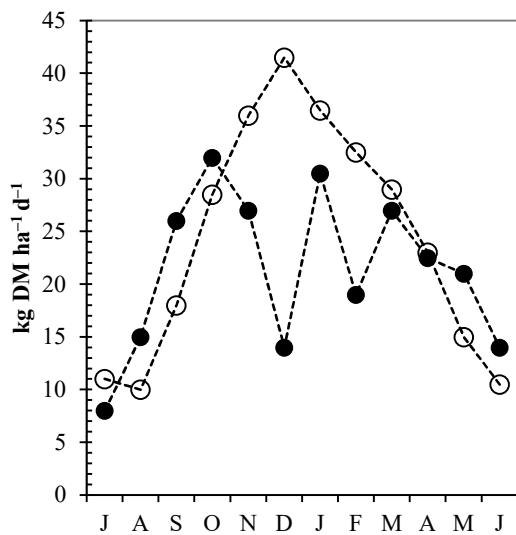
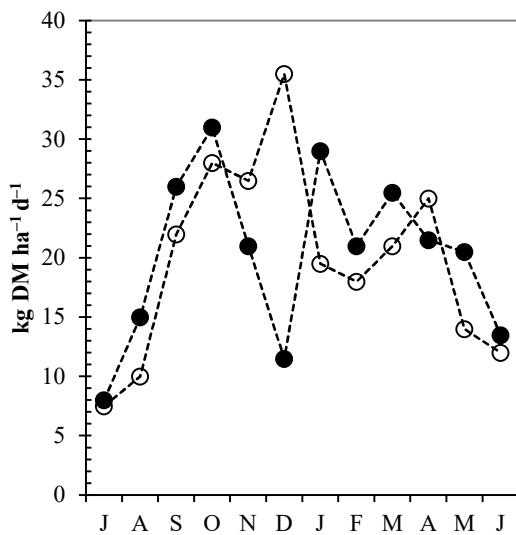


Figure S1. Annual Pasture Growth Index (average in red line) for New Zealand from 1977–2011 (Redrawn from NZXAGRI, 2012). “The national pasture growth index has a more stable long-term trend, although there has been significant downward movement in the past decade. The low PGI over the last few years is due mainly to drier than normal conditions.” – NIWA (NZXAGRI, 2012). PDF copy of the original report is available from J.G. on request.

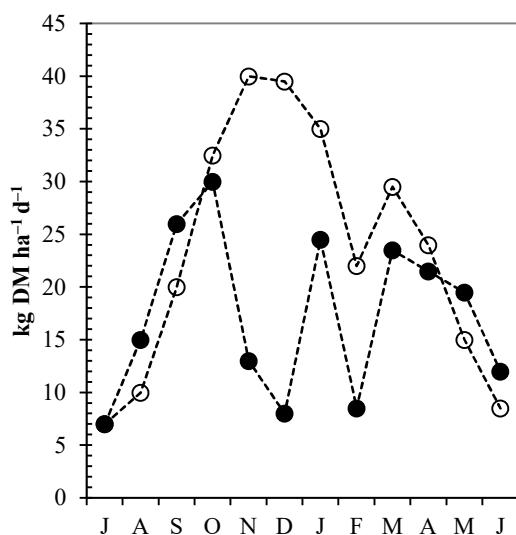
Farm A
1985–86 and 2010–11



Farm B
1980–81 and 2010–11



Farm C
1980–81 and 2010–11



Southern North Island Average System
1980–81 and 2010–11

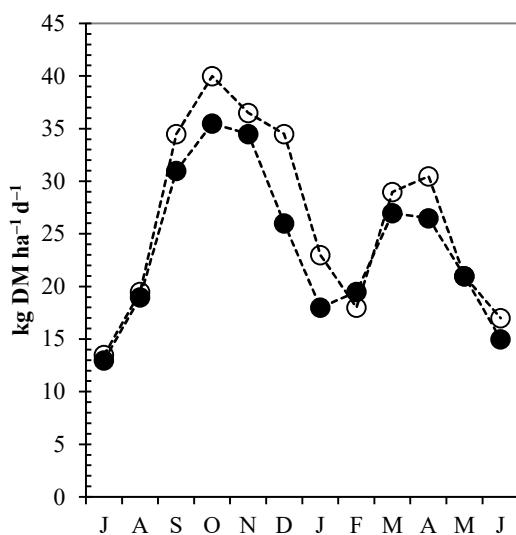


Figure S2. Seasonal herbage accumulation rates in the 1980s (○) and 2010–11 (●) based on actual data of Case-study Farms A, B and C and on statistics of the New Zealand southern North Island Average System (B+LNZ Class IV, medium slope, New Zealand southern North Island hill country sheep and beef cattle production systems).

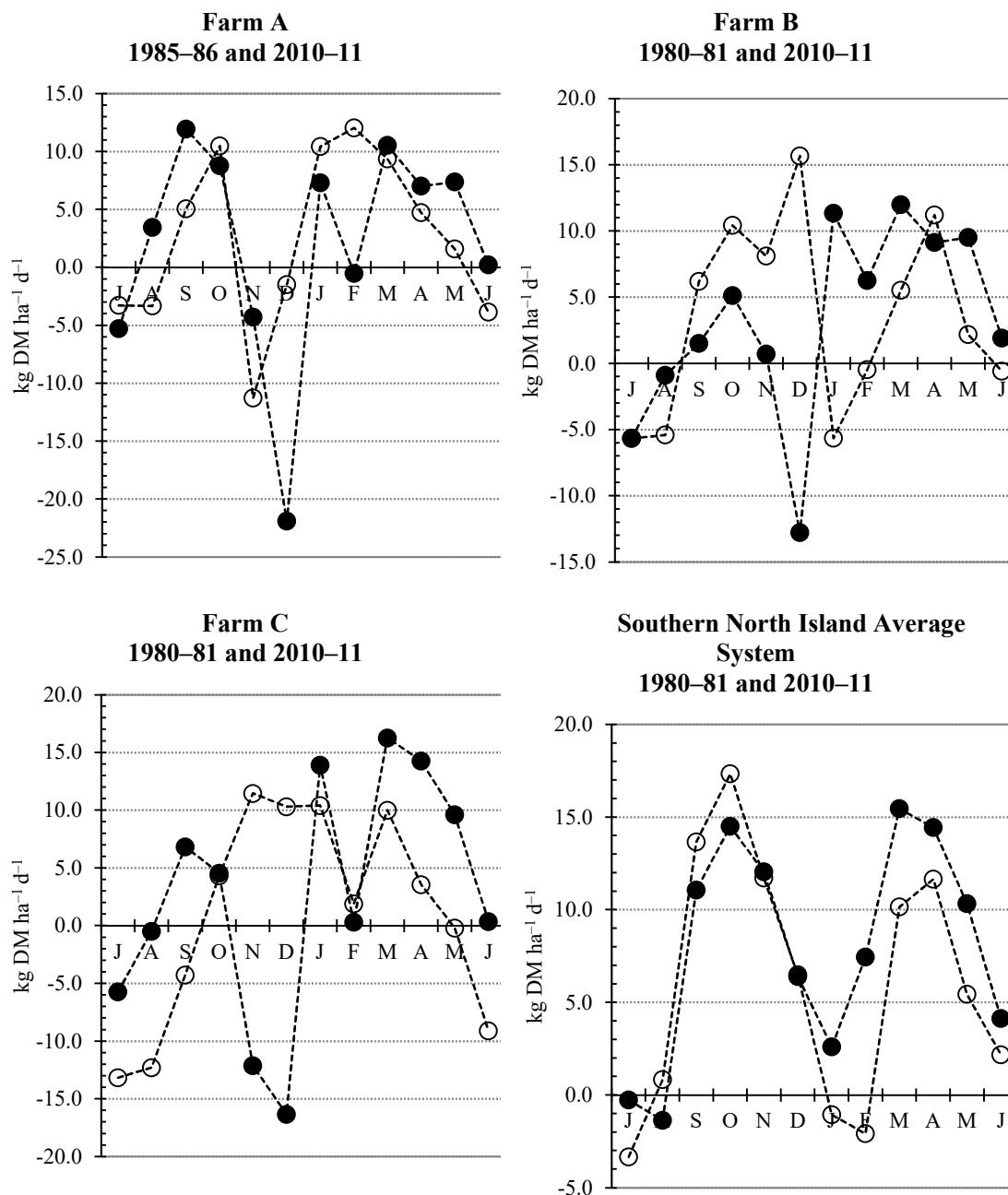


Figure S3. Feed balance (feed supply minus feed demand) in the 1980s (○) and 2010–11 (●) of Case-study Farms A, B and C and southern North Island Average System (B+LNZ Class IV, medium slope, New Zealand southern North Island hill country sheep and beef cattle production systems).