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# Effects of three whole-farmlet management systems on Merino ewe fat scores and reproduction

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**Abstract.** As part of the Cicerone Project's whole-farmlet experiment on the Northern Tablelands of New South Wales, Australia, the fat scores and reproductive performance of ewes were measured to assess the effect of different management systems on these important production parameters over time. The three farmlets (each of 53 ha) included one (farmlet B) subjected to 'typical' district management consisting of moderate levels of inputs and a target stocking rate of 7.5 dse/ha, with flexible grazing management across eight paddocks. A second farmlet (A) was managed in a similar fashion to farmlet B with respect to number of paddocks and grazing management, but modified by high rates of pasture renovation and higher levels of soil fertility, with a target stocking rate of 15 dse/ha. The third farmlet (C) was managed at the same level of moderate inputs as farmlet B but employed intensive rotational grazing over 37 paddocks and also had a high target stocking rate of 15 dse/ha. The experiment was conducted over 6.5 years from July 2000 to December 2006. In spite of the fact that target levels of stocking rate were chosen at the beginning of the experiment, stocking rate, together with fat scores and reproduction were treated as emergent properties of each farmlet system. Joining took place in April–May and lambing occurred in September–October of each year. Over the first 2 years of the experiment, there were few differences among farmlets in ewe fat scores or reproductive performance. From 2003 onwards, while the percentage of ewes pregnant was similar between farmlets, the average proportion of multiple births (ewes scanned in late July, with twins) was 30%, 16% and 12%, respectively, on farmlets A–C. However, lamb losses were greater on farmlet A, with average lamb mortalities recorded on farmlets A–C of 29%, 10% and 19%, respectively. Over the duration of the experiment, ewes on farmlets A and B were more often above a fat score level of 3, and less often below 2.5, than were ewes from farmlet C. Differences among farmlet ewes in fat score were found to be significant in 7 of the total of 13 assessments over the duration of the experiment. A generalised additive model applied to whole-farmlet data showed that green digestible herbage, legume herbage, stocking rate, the amount of supplement fed and especially the proportion of each farmlet grazed at any one time all influenced fat scores of ewes. While fat scores and conception rates tended to be highest on farmlet A, farmlet B had slightly better reproductive outcomes due to less lambing losses, whereas ewes on farmlet C tended to have somewhat lower fat scores and levels of reproduction. These farmlet-scale findings highlighted the importance for livestock managers to focus not only on grazing management, stocking rate and stock density during lambing, but also on the availability of sufficient green, and especially legume herbage, and the difficulty of overcoming a deficit in quality herbage with supplementation.

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## Introduction

The Northern Tablelands of New South Wales (NSW), Australia, support a range of grazing livestock enterprises dominated by fine wool and beef cattle (Alford *et al*. 2003). The region is subject to a variable, summer-dominant rainfall, with an average annual rainfall of ~780 mm and cold, frosty conditions in winter. Typically, sheep production systems in this region have adopted autumn joining and spring lambing, following shearing in late winter; hence, ewes are often under nutritional stress in late winter. As a consequence, managing ewe nutrition to maintain adequate energy reserves for pregnancy and lactation, leading ultimately to reproductive success, is known to be difficult.

In a 7-year study on the Northern Tablelands of NSW, Langlands *et al*. (1984) demonstrated large effects of nutrition and stocking rate on all aspects of Merino sheep reproduction, including ewe liveweights and, especially, a large effect of stocking rate on lamb survival. Liveweight has been shown to be linked to conception and ovulation rates, and, therefore, to the number of foeti detected by ultrasound scanning (Cumming 1977; Ferguson *et al*. 2011; van Burgel *et al*. 2011), and, potentially, to the number of lambs marked per ewe joined. The latter is a major contributor to financial profitability of most sheep production systems (Young *et al*. 2011). Further, these researchers reported an optimal annual liveweight profile for ewe reproductive success, which differs slightly for different regions and seasons of joining. Lambs marked per ewe joined reflects an accumulation of reproductive components, including ovulation rate, conception, lambs born and lambs surviving, and all are influenced by the nutritional state of the ewe.

Liveweight and body energy reserves at different stages of the reproductive cycle are widely assumed to reflect changes in potential reproductive efficiency, but liveweight is generally seen as more reliably positively correlated with the number of foeti scanned per ewe joined which, in turn, depends on ovulation and conception rates (Cumming 1977; Behrendt *et al*. 2011; Ferguson *et al*. 2011). However, fat or condition score, which reflect ewe energy reserves (Yates and Gleeson 1975; Shands *et al*. 2009; van Burgel *et al*. 2011), may be of greater importance in determining lamb survival and early growth.

Lollback and Hatcher (2007) presented an annual fat score profile for ewes in the New England region of NSW (which encompasses the Northern Tablelands region) with target critical times during the year such as weaning, joining, Day 100 of pregnancy and pre-lambing. They argued that when these fat score targets are met, it is likely that ewe reproduction levels will be close to genetic potential; when fat score (energy reserve) targets are not met, production losses are likely. The review of Hinch (2009) illustrated the importance of body energy reserves in influencing lamb survival.

As part of the Cicerone Project (Sutherland *et al*. 2013), a broad, grazed agro-ecosystem experiment was conducted to investigate the profitability and sustainability of three different management systems. The design of this experiment and the choice of treatments have been described in a related paper by Scott *et al*. (2013*a*). The present paper reports on two important dimensions of livestock production, namely fat scores and reproductive performance of ewe flocks, managed within the three different farmlet management systems over the duration of the experiment. Liveweights of all animals grazing the farmlets, including breeding ewes, have been reported in a related paper by Hinch *et al*. (2013). Several other facets of this experiment have been reported in related papers in this Special Issue, such as the planning of the experiment, the guidelines adopted, soil-fertility changes, pasture botanical composition, herbage mass and quality, remote sensing of pastures, the balance between feed supply and animal demand, wool production and its quality and value, intestinal worm control and economic outcomes.

The hypothesis tested here was that either or both farmlet A, with its higher inputs, and/or farmlet C, with its intensive rotational grazing management, would result in higher fat scores than, and superior reproduction of ewes compared with the animals under the typical management employed on farmlet B, and that this would be linked to the differences in quantity and quality of feed available on the different farmlets.

## Materials and methods

The farmlet experiment of the Cicerone Project was conducted ~17 km south of Armidale, on the Northern Tablelands of NSW, which is a temperate, summer-dominant, high-rainfall region of Australia. More details of the climate of the region and the weather experienced over the experimental period have been provided in a related paper by Behrendt *et al*. (2013).

Whereas the overall management guidelines and the different treatments applied to the three farmlets (each of 53 ha) have been described in detail by Scott *et al*. (2013*a*), details specific to the present paper will be described further below. In brief, farmlets A and B differed in levels of inputs while farmlets B and C differed in grazing management. Farmlet B was designed to represent a system considered by Cicerone producer members to be typical of management in the Northern Tablelands region. It aimed at a moderate level of soil fertility (20 mg/kg soil (bicarbonate) phosphorus and 6.5 mg/kg soil ($KCl_{40}$) sulfur) and pasture renovation, had a moderate target stocking rate of 7.5 dse/ha and employed flexible grazing management over its eight paddocks, according to Prograze principles of pasture and livestock condition (Bell and Allan 2000). Thus, management aimed, through regular monitoring of pastures and livestock, to maintain both green herbage mass and animal condition within the critical target levels recommended by the Prograze extension program.

Farmlet A also had eight paddocks and the same grazing management as did farmlet B but differed by having a higher soil-fertility target of soil phosphorus (60 mg/kg) and sulfur (10 mg/kg), a higher level of sown pastures, and a higher target stocking rate of 15 dse/ha. Farmlet C had the same moderate soil fertility and pasture renovation regime as did farmlet B but differed by employing intensive rotational grazing over its 37 paddocks and had the same higher target stocking rate as did farmlet A.

When the experiment began in July 2000, all farmlets had equivalent initial conditions (Scott *et al*. 2013*b*), including numbers and class of livestock, which were allocated randomly and in equal numbers to each farmlet at the commencement of the experiment. As treatments were implemented, such as pasture renovation, changes to soil fertility and grazing management, the characteristics of the soils (Guppy *et al*. 2013), pastures (Shakhane *et al*. 2013*a*, 2013*b*) and livestock (Cottle *et al*. 2013; Hinch *et al*. 2013) changed in response to management, climate and season.

The livestock enterprises on each farmlet were principally self-replacing Merino sheep with some cattle grazed over the spring to autumn period when feed surpluses occurred. To assess the capacity of each management system to provide adequate nutrition for breeding ewes, ewe fat scores were assessed on each of the farmlets at regular intervals, especially around joining in autumn, from April 2001 to May 2006. These measurements were compared with the target fat score profile developed for this region within the Lifetime Wool project (Lollback and Hatcher 2007). Reproduction was also assessed each year, with pregnancy scans conducted in July of 2003 to 2005, while lambing results were recorded each spring.

Detailed records of the grazing movements of each livestock mob across all paddocks and subpaddocks, reported in the companion paper on liveweight changes (Hinch *et al*. 2013), were maintained with the aid of weekly stock-record sheets which, together with all other experimental data, were entered into a relational database created for managing all Cicerone Project data (Scott *et al*. 2013*a*). Records of sheep mortality were kept on these stock-record sheets when substantial numbers of livestock died. However, detailed records of all other occasional sheep deaths were not kept, being embedded within the changes in animal numbers per mob over time. Because the experiment was run as a whole-farmlet trial, which allowed several factors such as stocking rate to evolve as emergent properties of each system, no attempt was made to standardise mob sizes, age of animals and numbers culled each autumn before joining. The numbers of ewes, wethers and hoggets culled or sold each autumn depended on assessments of the likely pasture growth anticipated in the coming winter, along with assessments of animal liveweights and fat scores. We acknowledge that these management decisions have influenced effects such as fat score but contend that this reflects realistic management on full-scale farms.

### *Management of animals*

A self-replacing flock of fine-wool Merino ewes (age range of ~5 years) was run on each of the farmlets commencing in July 2000, with 379, 378 and 378 ewes on farmlets A–C, respectively. In the first 2 years, ewes were joined with 2% of rams randomly allocated to each farmlet from the same fine wool stud source. Subsequently, to minimise the chances for genetic differences among farmlets, these same rams were joined with ewes from all farmlets when all were run together on the peripheral paddocks surrounding the farmlet area during joining. The joining period was over 6 weeks during April–May. As the farmlets diverged in performance in response to treatments, some unavoidable differences in the age cohorts of livestock developed due to different numbers of old ewes culled and/or maiden ewes joining the ewe flocks. Although these minor differences in age structure would have affected fat scores and reproduction, these changes were viewed as accurate reflections of what happens under different management regimes on full-scale farms, and hence were considered relevant emergent properties of each system. Some additional details of animal management, especially in relation to liveweight changes, have been provided in a related paper by Hinch *et al*. (2013).

Adult sheep were crutched in late summer–early autumn, before joining in April–May. Shearing took place in late July or early August. Lambing usually commenced around mid-September with weaning occurring from mid-December to early January. Ewes were weighed around joining, and at ~80 days of pregnancy and at weaning. Fat scores (Shands *et al*. 2009) were recorded less regularly than were liveweights but were carried out by the same assessor, around joining, mid-pregnancy and weaning in most years.

From 2003 to 2005, ewes from each farmlet were scanned using trans-abdominal ultrasound (Fowler and Wilkins 1982), at ~80 days from the start of joining, to determine their pregnancy status. Thereafter, the single- and twin-bearing ewes on farmlets A and B were grazed separately, with the twin-bearing ewes given access to paddocks assessed to have the greatest availability of green digestible herbage (Shakhane *et al*. 2013*a*). No ewes were joined in 2006.

During the experiment, supplementary feeding strategies changed somewhat in response to changing farmlet guidelines imposed by the Cicerone Board; more complete details can be found in Scott *et al*. (2013*a*). Briefly, during 2000 and 2001, minor amounts of hay, protein supplement blocks and lupins were fed on farmlets A and B, while farmlet C ewes were fed a 'loose mix' ration 'Dry Lic', consisting largely of minerals with some grain, developed for intensive rotational grazing systems (Meredith Seed Co., Armidale, NSW, Australia), which was delivered on self-feeding trailers. To reduce the potential for confounding of the farmlet treatments due to differential feed supplements, from 2002 onwards, the supplement was standardised; this consisted generally of high protein sources such as lupins and cotton seed meal, but maize, as an energy-rich supplement, was also fed at times when there were low amounts of total herbage. In 2006, on farmlet A, bales of poor-quality silage harvested in late 2005 only on that farmlet were fed out on that farmlet during winter, providing a modest level of supplement.

Decisions regarding the frequency and level of supplementation were made weekly by the Farm Manager, in conjunction with the Cicerone Board, after taking into account regular monthly assessments of green and dead herbage mass on each paddock (Shakhane *et al*. 2013*a*), assessing the fat scores of subsamples of mobs, and occasionally calculating the level of feed required using the decision support tool GrazFeed (Freer *et al*. 1997). However, it should be noted that, as the amount of supplement fed per head per week increased, the desire by the producer-led Board to keep expenditure on supplements within 'realistic' limits at times constrained the amount fed to levels somewhat below that suggested using estimates provided by the GrazFeed tool.

### *Statistical methods*

As the farmlet experiment was unreplicated, the validity of statistical inferences drawn depended on the degree to which the farmlets were similar at the start of the experiment and the extent to which the repeated-measures of response variables were found to be associated with farmlet treatment, using statistical approaches appropriate for agro-ecological studies such as this. Further explanation of the statistical approaches adopted in the present experiment and the causal inferences that can be drawn have been discussed in a related paper by Murison and Scott (2013), which explains, together with remote-sensing findings reported by Donald *et al*. (2013), the evidence that the farmlets did not differ significantly at the start of the experiment.

Fat scores were treated as categorical measures. Differences in fat scores of ewes among farmlets were explored across the 13 measurement dates by using ordinal logistic Bayesian regression using the arm package (Gelman *et al*. 2012) of the statistical program R (R Development Core Team 2011).

Fat score, liveweight and pregnancy scanning data were all examined for relationships with a wide range of explanatory variables by using the software 'Brodgar' (version 2.7.2, Highland Statistics, Newburgh, United Kingdom) that links to the statistical program R (R Development Core Team 2011). Data were examined for normality and found not to require transformation. Pair-plots (Zuur *et al*. 2007) were used to assess the degree of correlation between response and explanatory variables as Pearson correlation coefficients.

A generalised additive model (Zuur *et al*. 2007) was used to examine the significance of a wide array of potential explanatory factors on fat scores, such as ewe age (Age), green digestible herbage (G_DDM), legume herbage (LegDM), stocking rate (SR), grazed proportion (GP), supplementary feeding (MJ_ewe), day of year (cos_DOY), date (Date), and two-way interactions between Date and G_DDM, LegDM, SR, GP and MJ_ewe.

Multivariate modelling was carried out with redundancy analysis (RDA, Zuur *et al*. 2007) to examine those factors that, collectively, significantly affected the response variables of fat score, liveweight and pregnancy-scanning outcome of ewes. The scanned number of foeti determined in late pregnancy (August of 2003–2005), ewe fat score and liveweight at joining (in April of each year), were examined, with an array of explanatory factors averaged over the 4 months (January to April) before joining in that year. These factors were legume herbage, green digestible herbage, supplement fed, stocking rate and grazed proportion (the proportion of each farmlet grazed at any particular time, which served as a single surrogate for grazing management treatment).

## Results

### *Ewe fat scores*

Figure 1 shows the average fat scores of ewes for the different farmlet flocks measured at regular intervals from April 2001 to May 2006, together with the fat-score target profile for Merino ewes in the Northern Tablelands region (Lollback and Hatcher 2007). It is noteworthy that ewes on farmlets A–C were all below the target fat scores on most occasions, with animals on farmlet C being below a score of 3 on all but two occasion (2005 and 2006). In all farmlet systems, ewes reached their lowest average fat score at weaning time.

A Bayesian regression analysis of fat scores over time allowed comparison of the fat scores of ewes on farmlets A and C each to be contrasted with those of ewes on the control farmlet (B). The coefficients and their *P*-values, presented in Table 1, showed that, of the 13 dates when fat scores were measured, there were significant ($P < 0.05$) differences between the ewe fat scores on farmlets A and B on two of those dates, while fat scores on farmlets B and C differed significantly on five dates.

A fitted GAM model confirmed the complexity of the factors that affect ewe fat scores. The main effects of Age, G_DDM, GP, MJ_ewe, cos_DOY and Date and the two-way interactions between Date and G_DDM, LegDM, SR, GP and MJ_ewe were all found to be highly significant ($P < 0.001$). Together, they explained some 37% of the deviance in ewe energy reserves as assessed by fat score.

Figure 2 shows the trends observed in mean ewe fat score, together with the mean values over the same time intervals of the significant covariates of green digestible herbage, legume herbage, stocking rate, grazed proportion and supplement fed. More details of these parameters can be found in related papers, as follows: for herbage mass Shakhane *et al*. (2013*a*), for stocking rate and grazed proportion Hinch *et al*. (2013) and for supplement fed Scott *et al*. (2013*a*).

In general, farmlet A had greater amounts of green digestible herbage and legume herbage, whereas it had a substantially higher stocking rate and a higher level of supplementary feeding towards the end of the experiment than did either farmlet B or C, both of which had similar levels of these significant covariates (Fig. 2). The largest difference among farmlets was in grazed proportion, with farmlets A and B having similar but much higher levels than farmlet C. Because farmlet C tended to have lower fat scores than the other two farmlets up to January 2005, and yet had levels of other covariates similar to those of farmlet B up to that time, it is likely that these lower scores were due to the much lower level of grazed proportion due to its short graze periods and long rest periods (Hinch *et al*. 2013). However, in April and August of 2005, ewes on farmlet C had higher fat scores than on those on farmlet B; it is postulated that this may have been associated with a change late in the experiment to shorter rest periods (Hinch *et al*. 2013), which is reflected in a smaller difference in grazed proportion between farmlet B and C (Fig. 2) and/or a decline in sown perennial grasses observed on farmlet B at that time (Shakhane *et al*. 2013*b*).

### *Reproduction*

The percentage of lambs weaned in the first year of the trial (2000) was low for all three of the farmlets (Table 2). The fact that ewes were purchased after joining meant that farmlet differences in this first year were largely a reflection of lamb survival, not conception differences. The range in lambs weaned from 2001 onwards was more typical of commercial levels (63–99%), with farmlet C having, on average, a lower weaning rate than on farmlets A and B (Table 2).

Table 3 shows that, over the years from 2003 to 2005, there was relatively little difference among farmlets in pregnancy rate but there were substantial differences among years and farmlets in conception rate (scanning % or foeti/ewe joined) and twinning rate (proportion of twin foeti/pregnant ewe). Overall, farmlet A tended to have the highest conception and twinning percentages while ewes on farmlets B and C tended to have lower and similar percentages. In 2003 and 2004, farmlet A had 30% and 10%, respectively, more lambs at scanning (conception) than did farmlet C, but final weaning percentages were similar for all farmlets (Table 3). This reflects the higher lamb mortality, particularly in 2003, seen on farmlet A (37% of potential foeti) than on farmlets C (22%) and B (14%). The mean fat scores and liveweights of ewes also shown in Table 2 indicated lower liveweights on farmlet C than on farmlet B, which in turn had lower liveweights than did farmlet A ewes, whereas overall average fat scores were similar between farmlet B and C ewes but both were somewhat lower than those of farmlet A ewes.

### *Multivariate relationships between liveweight, fat score and scan*

Exploratory pair-plots of fat score, pregnancy scans and ewe weight with an array of potential explanatory variables showed

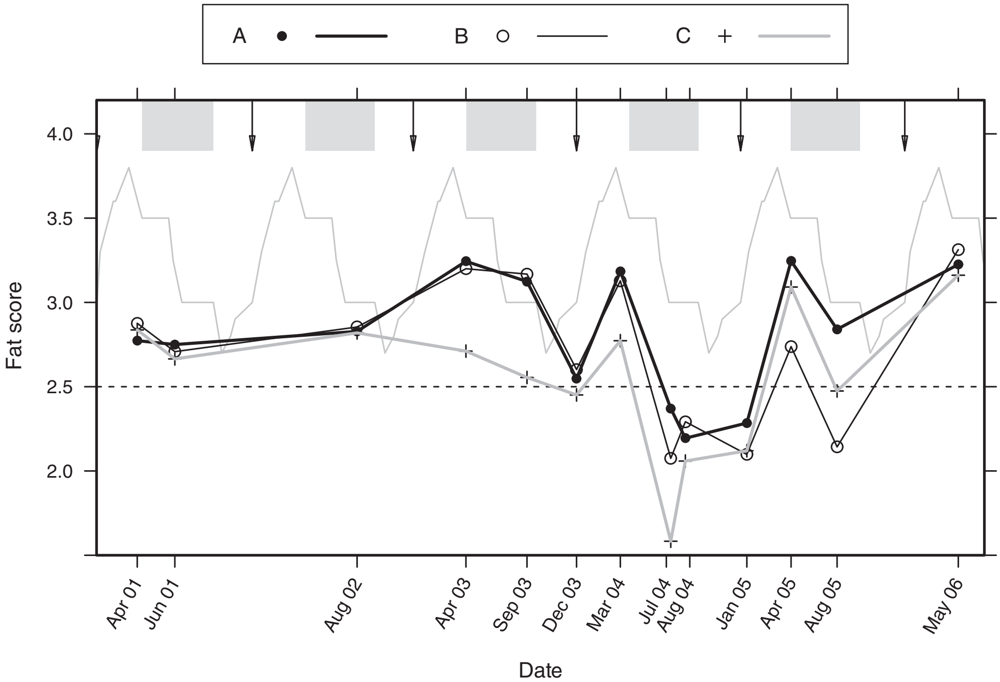


**Fig. 1.** Average fat scores of ewes on farmlets A–C from 2001 to 2006, together with the fat-score profile recommended for the Northern Tablelands region by the Lifetime Wool project (grey line). The grey shaded area at the top of the figure indicates the joining to lambing period, while the arrows indicate weaning dates in each year. The dotted line shows the minimum target fat score for ewes aimed at over the experiment.

**Table 1. Coefficients, standard errors, *t*-values and *P*-values from ordinal logistic Bayesian regression analysis of ewe fat-score data, showing contrasts between ewes on either farmlet A or C and the control, farmlet B, ewes over 13 sampling periods from April 2001 to May 2006**

**, $P < 0.01$; *, $P < 0.05$; n.s., not significant

| Date | Contrast | Value | s.e. | *t*-value | *P*-value | Significance |
|---|---|---|---|---|---|---|
| 3 Apr. 2001 | Farmlet A vs B | 0.48 | 0.27 | 1.81 | 0.212 | n.s. |
| | Farmlet B vs C | 0.28 | 0.27 | 1.03 | 0.413 | n.s. |
| 27 June 2001 | Farmlet A vs B | –0.28 | 0.26 | –1.07 | 0.398 | n.s. |
| | Farmlet B vs C | –0.50 | 0.26 | –1.90 | 0.197 | n.s. |
| 13 Aug. 2002 | Farmlet A vs B | 0.11 | 0.31 | 0.34 | 0.767 | n.s. |
| | Farmlet B vs C | 0.03 | 0.36 | 0.08 | 0.942 | n.s. |
| 16 Apr. 2003 | Farmlet A vs B | –0.13 | 0.20 | –0.68 | 0.566 | n.s. |
| | Farmlet B vs C | –2.33 | 0.23 | –10.14 | 0.010 | * |
| 1 Sep. 2003 | Farmlet A vs B | 0.21 | 0.20 | 1.06 | 0.400 | n.s. |
| | Farmlet B vs C | –2.30 | 0.22 | –10.30 | 0.009 | ** |
| 22 Dec. 2003 | Farmlet A vs B | 0.12 | 0.19 | 0.65 | 0.584 | n.s. |
| | Farmlet B vs C | –0.16 | 0.19 | –0.84 | 0.489 | n.s. |
| 30 Mar. 2004 | Farmlet A vs B | –0.20 | 0.18 | –1.14 | 0.373 | n.s. |
| | Farmlet B vs C | –1.56 | 0.19 | –8.11 | 0.015 | * |
| 22 July 2004 | Farmlet A vs B | –1.05 | 0.45 | –2.33 | 0.145 | n.s. |
| | Farmlet B vs C | –3.26 | 0.58 | –5.64 | 0.030 | * |
| 24 Aug. 2004 | Farmlet A vs B | 0.28 | 0.20 | 1.40 | 0.297 | n.s. |
| | Farmlet B vs C | –0.46 | 0.20 | –2.30 | 0.148 | n.s. |
| 10 Jan. 2005 | Farmlet A vs B | –0.49 | 0.18 | –2.68 | 0.116 | n.s. |
| | Farmlet B vs C | –0.34 | 0.18 | –1.82 | 0.210 | n.s. |
| 20 Apr. 2005 | Farmlet A vs B | –2.01 | 0.21 | –9.37 | 0.011 | * |
| | Farmlet B vs C | –0.65 | 0.20 | –3.31 | 0.080 | n.s. |
| 2 Aug. 2005 | Farmlet A vs B | –2.90 | 0.23 | –12.44 | 0.006 | ** |
| | Farmlet B vs C | –1.51 | 0.21 | –7.18 | 0.019 | * |
| 3 May 2006 | Farmlet A vs B | 0.26 | 0.16 | 1.62 | 0.247 | n.s. |
| | Farmlet B vs C | –0.27 | 0.16 | –1.62 | 0.247 | n.s. |

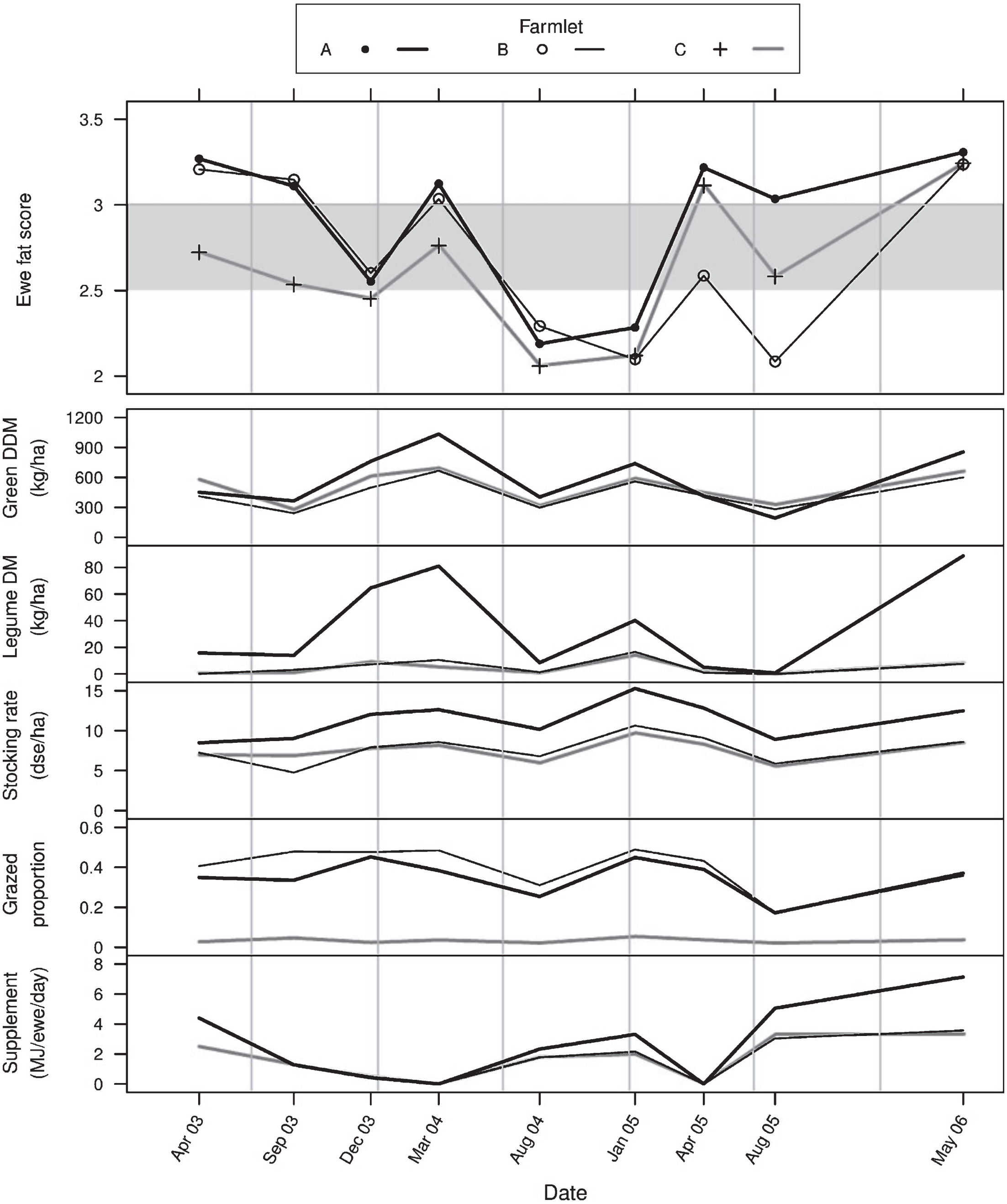


**Fig. 2.** Trends in (*a*) mean ewe fat score (with grey band indicating desirable range) and significant covariates, (*b*) green digestible herbage (Green DDM), (*c*) legume herbage (Legume DM), (*d*) stocking rate, (*e*) grazed proportion and (*f*) supplement fed on farmlets A–C from April 2003 to May 2006.

that the factors with the higher Pearson correlation coefficients were as follows: for fat score, LegDM (+0.23) and SR (–0.22); for scan, Age (+0.32), year (Year) (–0.29) and supplement fed (Suppl) (–0.27); and for liveweight, Age (+0.49), LegDM (+0.43), GP (+0.36) and SR (+0.35).

The RDA of 1510 records of ewes over the 3 years that pregnancy scans were conducted (2003 to 2005) showed that fat score and liveweight at joining and pregnancy scan (conception rate) were significantly ($P < 0.01$) correlated with, in a decreasing order of the proportion of variance explained, Age, LegDM, Year, Suppl, G_DDM, SR and GP. The sum of canonical eigenvalues showed that these relationships explained some 21% of the variation; Axis 1 and Axis 2 explained some 73% and 18%, respectively, of that variation.

Because the factors of SR and GP were collinear, two separate RDA analyses were conducted with each of these factors included in separate but similar analyses. The

**Table 2. Number of ewes joined, number and percentage of lambs weaned and average liveweight and fat score of ewes (before joining) on farmlets A–C in each year when ewes were joined from 2000 to 2005 inclusive**

| Year | Ewes joined | | | Number weaned | | | Percentage weaned (%) | | | Liveweight (kg) | | | Fat score | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 2000 | 379 | 378 | 378 | 213 | 201 | 178 | 56 | 53 | 47 | | (n/a) | | | | |
| 2001 | 109 | 103 | 97 | 100 | 90 | 81 | 92 | 87 | 84 | 43.7 | 44.4 | 43.7 | 2.6 | 2.6 | 2.8 |
| 2002 | 105 | 117 | 95 | 68 | 88 | 60 | 65 | 75 | 63 | 43.7 | 49.0 | 45.4 | | (n/a) | |
| 2003 | 258 | 138 | 130 | 204 | 125 | 100 | 79 | 91 | 77 | 51.0 | 49.1 | 43.0 | 3.3 | 3.2 | 2.7 |
| 2004 | 269 | 173 | 153 | 264 | 171 | 148 | 98 | 99 | 97 | 52.4 | 50.8 | 47.4 | 3.1 | 3.0 | 2.8 |
| 2005 | 201 | 171 | 158 | 134 | 110 | 100 | 67 | 64 | 63 | 51.0 | 44.8 | 45.9 | 3.2 | 2.6 | 3.1 |
| Total/average | 1321 | 1080 | 1011 | 983 | 785 | 667 | 74 | 73 | 66 | 48.4 | 47.6 | 45.1 | 3.1 | 2.9 | 2.9 |

**Table 3. Pregnancy, conception and twinning rates (determined by scanning) on the three Cicerone farmlets (2003–2005)**

| Year | Farmlet A | Farmlet B | Farmlet C |
|---|---|---|---|
| | *Pregnancy rate (%)* | | |
| 2003 | 92.5 | 94.1 | 94.5 |
| 2004 | 94.0 | 95.4 | 95.9 |
| 2005 | 86.3 | 78.0 | 77.7 |
| Average | 90.9 | 89.2 | 89.4 |
| | *Conception rate (%)* | | |
| 2003 | 142.0 | 121.0 | 113.0 |
| 2004 | 119.0 | 111.0 | 109.0 |
| 2005 | 101.0 | 84.0 | 83.0 |
| Average | 120.7 | 105.3 | 101.7 |
| | *Twinning rate (%)* | | |
| 2003 | 49.6 | 26.5 | 18.1 |
| 2004 | 25.0 | 15.3 | 13.1 |
| 2005 | 14.2 | 6.0 | 5.7 |
| Average | 29.6 | 15.9 | 12.3 |
| | *Lamb mortality (%)* | | |
| 2003 | 43 | 9 | 28 |
| 2004 | 12 | 3 | 11 |
| 2005 | 31 | 17 | 19 |
| Average | 29 | 10 | 19 |

resulting two biplots from the analyses (Fig. 3) showed that fat score was most closely related to GP, suggesting that farmlets A and B tended to have higher fat scores than did farmlet C because of the higher proportion of those farmlets grazed at any one time. Further, fat score tended to be positively correlated with higher levels of LegDM and G_DDM, which, on average, were higher on farmlet A in spite of its higher stocking rate (Fig. 2). The litter size at pregnancy scanning was most closely and positively correlated with Age and liveweight and negatively correlated with the level of supplement. Thus, heavier ewes at joining had a subsequently higher pregnancy scan rate but also required more supplement to achieve this. These ewes also had higher liveweights, which, in turn, was positively associated with higher LegDM and G_DDM and the SR (Fig. 3*a*) or GP (Fig. 3*b*). In contrast, there was no correlation between pregnancy scanning percentage and fat score at joining time.

## Discussion

The target fat score or condition score for ewes to optimise joining success has been outlined in several management programs such as Prograze and Lifetime Ewe Management (Anonymous 2010) and is reflected in the targets reported by Lollback and Hatcher (2007). When the annual fat-score patterns observed on the three farmlets were compared with such targets, it is clear that the animals in this experiment were more often than not below the recommended energy-reserve levels desirable for maximum reproductive performance. The animals were usually able to recover energy reserves by joining time, although not to the levels recommended for maximum reproductive efficiency. The ranking of the mean fat scores for the farmlets in different years was similar to the rankings for liveweight reported for these flocks by Hinch *et al*. (2013). In 2003, ewes on farmlet C were half a fat score below the ewes on the other two farmlets, a pattern that persisted in 2004 and 2005, suggesting that animals on farmlet C were unable to recover adequate energy stores at strategic points of the reproductive cycle, most notably after weaning, to attain target fat scores. This was also apparent for other farmlets in the years of 2004 and 2005 when below-average soil-moisture conditions constrained pasture supply (Behrendt *et al*. 2013) and, in the case of farmlet A, a higher stocking rate was attained.

Many factors (most notably Age, LegDM, G_DDM, GP, Suppl, SR and Year) were shown to influence ewe fat score; the biplots of the RDA illustrated that the fat score was influenced to a similar degree by the pasture parameters (LegDM and G_DDM) as well as by grazing management (represented by GP and SR). This may be related to the link between the capacity of the animals to selectively graze high-quality feed, especially when higher amounts of herbage are available (Arnold 1960; Baumont *et al*. 2000; Chen *et al*. 2002; Piasentier *et al*. 2007). In contrast, the higher stock density imposed during grazing on farmlet C (Hinch *et al*. 2013) resulted in poorer average fat scores, presumably related to the lesser opportunity for selective grazing under this grazing regime, as reported by Shakhane *et al*. (2013*c*).

It is somewhat surprising that fat score was less well associated with pasture parameters than was liveweight, as it is generally perceived that fat score or condition are a reflection of energy status. Behrendt *et al*. (2011) concluded that management using either liveweight or condition score/fat

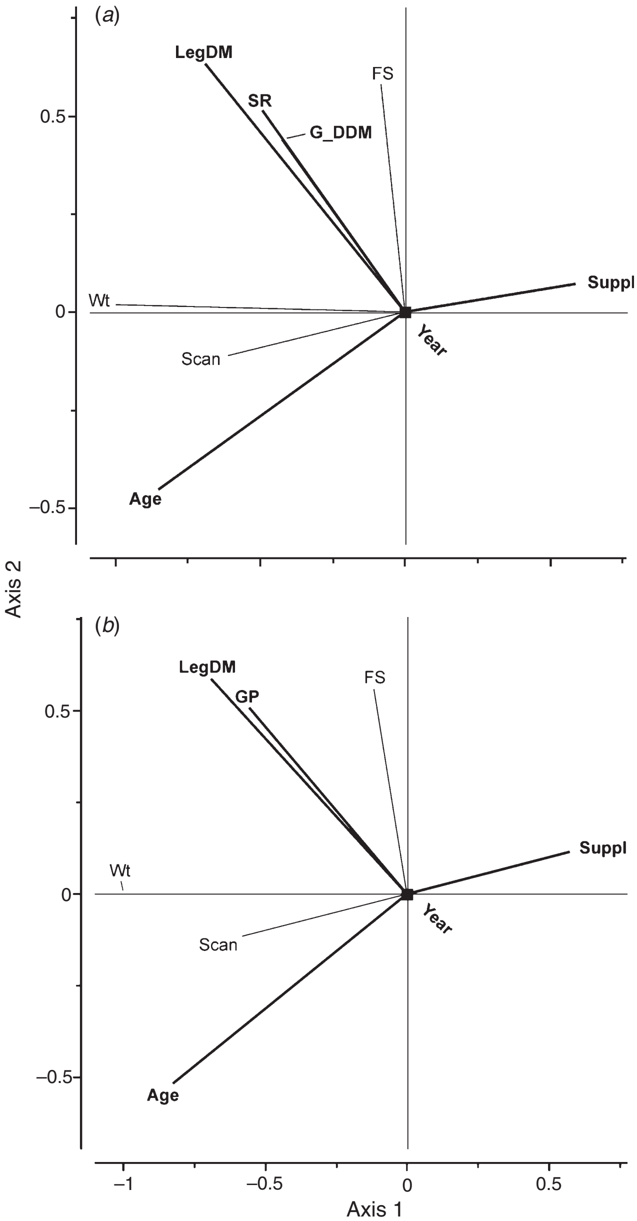


**Fig. 3.** Biplots from redundancy analysis (RDA), showing multivariate relationships among continuous response variables (thin lines) (fat score (FS), scan (Scan) and liveweight (Wt)), and significant explanatory variables (continuous variables: thick lines; nominal variables: squares) of supplement (Suppl), year (Year), ewe age (Age), legume herbage (LegDM) and (*a*) stocking rate (SR) and green digestible herbage (G_DDM) and (*b*) grazed proportion (GP) over prior 120 days. Lines separated by small angles indicate positive correlations; lines separated by angles approximating 180° suggest strong negative correlations, while lines with angles approaching 90° indicate little or no correlation between factors.

score profiles allow predictable increases in reproductive performance of both ewes and their progeny and it seems from the biplot that liveweight may be more closely related to pregnancy scanning outcomes than is fat score. However, this may reflect a greater repeatability for the measurement of liveweight than of fat or condition score (Shands *et al*. 2009; van Burgel *et al*. 2011) or simply the larger amount of liveweight data collected.

The patterns shown here for changes over years affirm that, unless feed of adequate quality and quantity is available post-weaning, fat score will not recover adequately to allow the ewes to reach their reproductive potential at the subsequent joining. The present data from the Cicerone farmlets have demonstrated the difficulty of reaching target fat scores in all seasons in the pasture environment of the Northern Tablelands, particularly for the intensive rotational grazing system of farmlet C, with its employment of high stock densities during grazing periods. No matter what pasture management/utilisation system graziers adopt, it has been suggested that it must deliver either by pasture alone or, in conjunction with appropriate supplements, target fat scores of ~3 to maximise the reproductive potential in the flock.

According to Saul *et al*. (2011), a trial in south-western Victoria over 6 years showed that grazing systems with upgraded pastures resulted in a 75% increase in stocking rate, a higher condition score by 0.3, 13% more lambs born and 6% more lambs marked and weaned, all without any increase in the level of supplementary feed required. Therefore, it could be expected that the farmlets might also differ in reproductive efficiency; given the fat scores were below target (score of 3), reproductive performance is likely to have been below the potential for fine wool (16 µ) ewes.

It can be seen from the average conception rates that all ewe groups had production levels that could be considered close to those of industry average (Kleemann and Walker 2005*a*). There was a clear association of twinning levels and conception rate with liveweight and fat score, similar to the associations described by Ferguson *et al*. (2011) between liveweight and foeti per ewe joined. While the twinning rates were lower in 2004 than in 2003, there was, nevertheless, a similar trend among farmlets, with farmlets with heavier and fatter ewes on average having better reproductive performance.

There was considerable variation among years and among farmlets in conception rate (based on pregnancy-scanning data) but this might be expected as it is well known that ovulation and oestrus are influenced by nutritional status (Cumming 1977). The major issue for each system is probably the degree of recovery in fat score (energy store) during the weaning to joining period, and the ability of the management system to maintain adequate fat scores not only throughout early and mid-pregnancy, but also the critical 50–60 days of late pregnancy and early lactation. The consequences of not achieving these targets or profiles can be significant for both the performance of the ewes and their progeny (Lollback and Hatcher 2007; Thompson *et al*. 2011).

The high rate of lamb mortality that occurred during one lambing period in October 2003, especially on farmlet A, is a pattern not unexpected for a high level of twinning, as mortality rates are usually more than double those of single lambs, particularly during cold and wet lambing conditions and where there is no shelter (Lynch *et al*. 1980). Clearly, in the 2 years when lambing percentages on farmlet A were high, the losses were also high, which could reflect the combination of low-birthweight twins (nearly 50% of ewes) and cold wet conditions at birth (particularly in 2003). However, losses on farmlet B during the same period were below what might have been expected for what was also a high proportion of twins (26.5%) and, therefore, factors other than poor weather conditions were also likely to have been important. Ewe density (farmlet A –13.5 ewes/ha) could have been a factor that contributed to mismothering and lamb losses (Lynch *et al*. 1980). Industry recommendations suggest that set stocking of twin-bearing ewes at stock densities greater than 20 ewes/ha will result in high mortalities (Anonymous 2008) and that highest survival is achieved with small mobs at low densities. Also, at the time the deaths occurred, although the paddock in which the twin-bearing ewes lambed had the highest amount of green herbage on that farmlet at that time, it was nevertheless considered suboptimal, being 1180 kg DM/ha of green herbage with a digestibility of 73%, well below the 1800 kg green DM/ha recommended in extension programs such as Making More from Sheep (Anonymous 2008).

Table 2 serves to outline the relatively high reproductive wastage observed on all of the Cicerone farmlet flocks of lambs born compared with the potential lambing rate. However, this problem is not unique to these flocks and is commonly identified throughout Merino industry flocks (Kleemann and Walker 2005*b*). The results presented here suggest caution in using lambing strategies that require high stocking densities (Robertson *et al*. 2012). Farm management decisions need to maximise reproductive potential by aiming for high liveweights at joining and then managing fat score through pregnancy by taking into account the available pasture and the need for appropriate feed supplements. In the environment of the Northern Tablelands, grazing ewes typically need supplementary feed through winter, particularly in late pregnancy. The data presented in the current study indicated that establishing the correct combination of grazing management and an affordable level of supplementation that result in adequate energy intake for breeding ewes is difficult to achieve, and especially during the conditions of drier-than-average soil moisture and colder-than-average winter temperature experienced during the present experiment (Behrendt *et al*. 2013).

Overall, there was a consistently poorer performance of the high-density stocked system, both in terms of energy stores and reproductive efficiency. Reproductive efficiency at joining was best explained by liveweight changes but fat score can also be used to monitor both joining efficiency and pregnancy needs. However, the large variation among years and throughout the year in ewe energy status makes management to reach reproductive potential difficult. Clearly, animals need to be closely monitored, with fat/condition score possibly being most useful for pregnancy management as, unlike liveweight assessment, body condition is not affected by the increasing contribution of the weight of the foetus and placenta during pregnancy.

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