The On-Farm Value of Animal Welfare

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Abstract

Concern over the welfare of animals used for agricultural production has grown noticeably over the last 20 years. Regulations of the European Union now state the need to preserve and improve animal welfare by preventing undesirable intensive farming.

This paper examines animal welfare in broadacre farming in a region of Western Australia. It examines the impact on farm profits of pursuing various management strategies that impact on animal welfare. Is there a trade-off between profit and animal welfare in broadacre farming ?

Keywords: animal welfare, farm management

Introduction

Interest over the care and welfare of animals used in agriculture has increased over the last 20 years. Farm animal welfare has become an area of study for some animal scientists (Broom, 1988, 1991). Increasingly in Europe (Bennett and Larson, 1995) farm animal welfare concerns are being incorporated in farm legislation. European Commission regulations in 1989 state the need to "preserve and improve the natural environment and animal welfare by preventing undesirable intensive farming". In the European Union legislative minimum standards apply to the transport of animals, care of laying hens, calves and pigs. In the United States of America the political debate about farm animal welfare appears to be intensifying (Tweeten, 1991;Rowan, 1993).

In Australia very stringent codes of practice apply to experimentation with farm animals and animal science courses in agricultural education institutions usually include animal husbandry and welfare modules. When farm animal welfare concerns are raised in Australia in the print and visual media it usually involves either intensive agriculture or the plight of animals in extensive agriculture experiencing the vicissitudes of drought, flood, heat, wind and cold. In broadacre farming the natural environment (e.g. drought) is often seen as the main cause of animal suffering rather than the management practices of the farmers. When farmers' animal management is questioned it is often not just because of its effect on animal welfare but also for its effect on the natural environment. For example, over-stocking that leads to animals being of low bodyweights and in poor condition is criticized for its impact on ground cover and natural vegetation as well as for the stress it places upon the animals.

Because of the seasonal patterns in feed production it is often seen as defensible that broadacre farmers allow animals to lose bodyweight and condition during periods of feed scarcity. Welfare concerns for these animals usually do not arise because most farmers either introduce supplementary feeding to avoid extreme loss of bodyweight or they allow the animals to recover condition before their sale. Although there are some farmers who by virtue of drought, stocking rate or feeding regimes do sell animals about which animal welfare concerns could be raised, the bulk of farmers appear to ensure that sheep flocks are maintained in reasonable condition. Farmers' own animal welfare concerns may cause them to ensure sheep flocks are maintained in reasonable condition or they may find their farm businesses are more profitable with sheep maintained and sold in reasonable condition. This last claim is examined in this paper.

The first section of the paper describes a crop-livestock farming system in a dryland agricultural environment within which sheep flocks are strategically managed. A model of this farming system is described briefly. The second section outlines various livestock management strategies, each with a particular animal welfare outcome, that are incorporated in the model. The third section examines the impact on farm profits and enterprise selection of these livestock management strategies. The final section draws conclusions and points out limitations in this examination of animal welfare in broadacre farming.

The Farming System

The animal welfare outcomes associated with different livestock management strategies are examined for the farming system of the Merredin region in Western Australia (see figure 1). The region has a Mediterranean climate with mild wet winters and hot dry summers. Farms in the regions have a mix of crop and livestock enterprises and average farm size is around 2700 hectares. The annual rainfall of the region is about 310mm with most falling from May to October, followed by a summer drought from December to March Crops are sown in May to July and harvested in November and December. Farm operations are highly mechanized and most farms are owner-operated with not more than one other permanent labourer. Casual labour is hired for only a few months of the year to assist in main tasks such as seeding, harvesting and shearing.

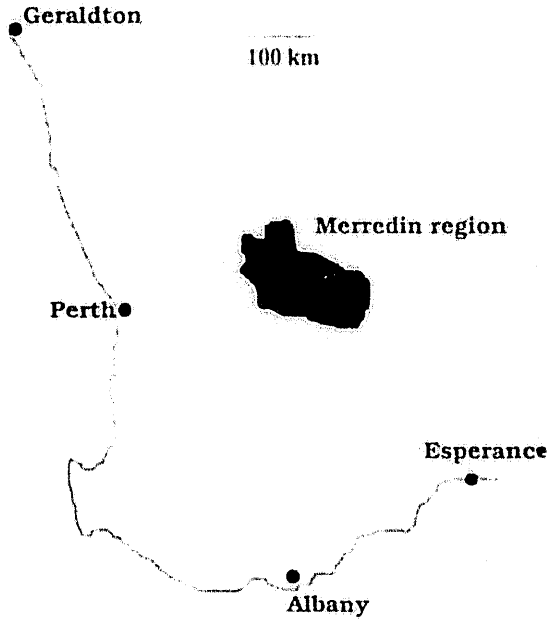


Figure 1: The Merredin region of Western Australia

Crops include mainly cereals with lesser areas of other crops such as canola or legume crops, lupins and peas. Livestock consist almost solely of Merino sheep for wool and meat production. Lambing is in late autumn or mid-winter and shearing is in spring and autumn. Sheep are run on annual pastures during winter and on a combination of crop residues and dry annual pastures in summer. The pastures contain volunteer annual grasses and herbs, with annual legumes introduced in many situations. Crops and pastures are commonly grown in rotation.

There are seven main soil types (Stoneman, 1992) within the region (see table 1). Most sandy soil classes in the regions are highly weathered and many are infertile requiring yearly applications phosphate and nitrogen to promote plant growth. The pastures grown on the seven soil types are based on subterranean clover, medics, annual ryegrass and volunteer grasses (barley grass, brome grass) and herbs (capeweed, geranium). Wheat yields average just over 1.1 tonnes per hectare.

Table 1 Soil Classes in the Eastern Wheatbelt Version of MIDAS

Soil class	Description	Ph Range	(ha)
S1 (Acid sands)	Yellow, loamy or gravelly sands. Native vegetation is wodgil with sheoak and banksia on deep white sands	< 5.5	500
S2 (Sandplain)	Deep, yellow brown loamy sands. Native vegetation is grevillea and tamma	5.5-6.0	500
S3 (Gravelly sands)	Yellow-brown gravelly sands and sandy gravels. Native vegetation is tamma	5.5-6.0	250
S4 (Duplex)	Grey, sandy loams, loamy sands, gravelly sands and sand over white clay with yellow or red mottles. Native vegetation is mallee	5.5-6.5	250
S5 (Medium heavy)	Red brown, sandy loam over clay sub soil. Native vegetation is salmon gum and tall mallee	6.0-7.0	375
S6 (Heavy non triable)	Dark red brown, sandy clay loams. Native vegetation is gimlet, morrel and salmon gums	> 6.5	500
S7 (Heavy triable)	Previous S6 soil treated with gypsum	> 6.5	125

A Model of the Farming System

A model of the farming system in this region is known as MIDAS (Model of an Integrated Dryland Agricultural System). Early versions of MIDAS are described in detail by Morrison *et al.* (1986) and Kingwell and Pannell (1987). Revised versions are described by Morrison and Young (1991), Pannell and Bathgate (1991, 1994) and Kingwell *et al.* (1995). The model is a mathematical programming model of a representative farm. It is a steady state model based on an expected weather-year. It assumes the farm manager is profit maximizing, although other managerial goals and behaviour are implicitly accounted for in the structure of activities. For example, part of leisure preferences are captured by the need to finish harvesting in early January. Typically farmers holiday off-farm in mid-January for a few weeks. Also soil conservation attitudes are reflected in restrictions on the degree to which feed can be removed by the grazing of sheep. The model is based on expected values and therefore assumes certainty of knowledge about prices, costs and input-output relationships. Output from the model is a set of profit maximizing enterprise and rotational activities as well as shadow price information about the marginal value of farm resources and alternative enterprise or rotational options. Farm profit is calculated as a net return to capital and management. This return equates to monies left over from production receipts after deducting all operating costs, overhead costs, depreciation and opportunity costs associated with farm assets (exclusive of land).

As explained by Kingwell (1987a) the model has been developed in consultation with farmers, researchers, advisers and farm management consultants and it emphasizes the interdependencies of crop and livestock enterprises. The model comprises a technical matrix of around 470 columns (or activities) with around 300 rows (or constraints). The model's framework is a single period equilibrium structure, inclusive of inter year effects that allows inter relationships between phases of rotations to be represented within the planning horizon of a single production year.

Broadly, the model describes the production alternatives on 7 soil classes. Up to 20 rotation options are described for each soil class. The crop options include wheat, oats, barley, white lupins, triticale, canola and field peas. The production of over 25 classes of merino sheep based on a self-replacing flock are depicted and allow for a myriad of flock sizes and structures. The type and quantity of wool produced by each sheep class is recorded along with their liveweight and wool sale prices. Pasture production on each soil class and in each rotation phase is also described. The non-linear yield responses of cereals to applied nitrogen on each soil class are described using the Duloy-Norton (1975) approximation.

Enterprise interdependencies are a feature of the models. The effects on cereal yields of previous leguminous pastures or legume crops are depicted. The increased weed burden in crops due to previous pastures is described as is the deleterious effect of cropping on subsequent pasture production.

Many sources of feed for livestock are described in the models, green and dry pastures, grain stored on-farm or bought in and crop residues including spilt grain as well as feeding restrictions on lupin stubble because of lupinosis risks. The effect of stocking rate on pasture production is outlined in the models. Also represented on a monthly basis are the energy requirements and appetite of each sheep class and energy sources and feed qualities within the farming system.

The model represents current farm management technology insofar as the types of tillage practices, machinery complements, herbicides used and rates applied, tasks contracted and crop and livestock options considered are all consistent with those used or being canvassed by leading farmers of the region. The model describes the major constraints on farm operations. These constraints include the physical limits imposed by farm size and areas of different soil classes. The limited supply of family labour and working capital are depicted as is the limited work capacity of farm machinery.

For a detailed exposition of the nature and structure of the models readers are referred to Morrison *et al.* (1986), Kingwell (1987b), Abadi Ghadim *et al.* (1991), Morrison and Young (1991), and Pannell and Bathgate (1991, 1994) and Kingwell *et al.* (1995).

Livestock Management Strategies

The management of livestock results in animals achieving various rates of growth. In describing the liveweight condition of animals (Jeffries, 1961) introduced the condition score index. For marketing purposes Jeffries categorised sheep into condition scores that mainly reflected the liveweight of the animal relative to the historically observed liveweights of sheep of similar age and sex (Russel *et al.*, 1969). For example, severely under-nourished sheep were ranked as condition score 0 which implied the animals were extremely emaciated and were near death. Sheep ranked as condition score 1 displayed symptoms of mal-nourishment. These animals had very low liveweights for their sex and age group. They had virtually no subcutaneous fat cover (AAC, 1990) and were therefore greatly exposed to heat, cold and wind stress, raising legitimate concerns for their welfare. Condition score 2 animals were lean, with low to average bodyweights for their age. These animals had little subcutaneous fat cover and some welfare concerns might be raised over these animals. Condition score 3 animals were fully muscled with moderate fat cover. The maximum condition score was 5 which included animals considered overly fat for their age and sex. The system introduced by Jeffries for sheep appraisal has subsequently been applied (Lowman *et al.*, 1976) to other animal groups (e.g. cattle, goats and pigs).

This paper examines livestock management strategies that result in sheep being broadly maintained at condition scores 1, 2, 3 and 4. It is assumed that lambs and hoggets are maintained to at least condition score 2. However, adult sheep are subject to management regimes that result in these sheep being mostly maintained at condition score 1, 2, 3 or 4. The derivation of the nutritional requirements of many various classes of sheep mainly was based on equations and data in Pannell and Bathgate (1994) who in turn drew on work by Rickards and Passmore (1977) and opinions of animal researchers. The nutritional requirements and production outcomes for sheep mostly maintained at certain condition scores used in MIDAS were also compared against those derived from feed equations found in AAC (1990) and GrazFeed (1993). Some production outcomes incorporated in MIDAS were based on anecdotal evidence or extrapolations from limited experimental data described in AAC (1990).

Animal production research (e.g. Pollott and Kilkenny, 1976, Morley *et al.*, 1978, Rogers *et al.*, 1979, Grainger *et al.*, 1982) shows how an animal's condition score affects its production performance. In the case of sheep, increasing the condition score of ewes increases ovulation rates and prospects for pregnancy. For example, Pollott and Kilkenny (1976) found that a one unit increment in the condition score of ewes at joining was associated with a 29 percent increase in lambs subsequently born. AAC (1990) note how changes to a sheep's condition score alter its body fat cover and affect its survival prospects during exposure to cold and heat stress.

Reducing feed available to an animal, for example by increasing stocking rate, can reduce the condition score of the animal and lead to a finer micron in wool being produced. The benefits of feed reduction and production of finer wool, however, might be offset by other negative impacts of loss of body condition. These impacts can include lower lambing percentages, lower wool yields, lower sale prices for animals in poorer condition and greater death rates. Further, the finer micron wool which attracts a higher price, can be subject to tenderness for which price discounts apply.

Jeffries (1961) indicated that a one unit change in condition score for Merinos and Corriedales corresponded to a 7 kg change in liveweight. AAC (1990) report regression analyses of liveweight on condition score for various Merino classes and they confirm the observations of Jeffries. The results of these regression analyses were used in generating liveweight patterns of sheep classes of various condition scores in MIDAS. Liveweight patterns for three year old adult ewes and wethers used in MIDAS are shown in figures 2a and 2b.

Figure 2a: Wet ewe liveweights at various condition scores

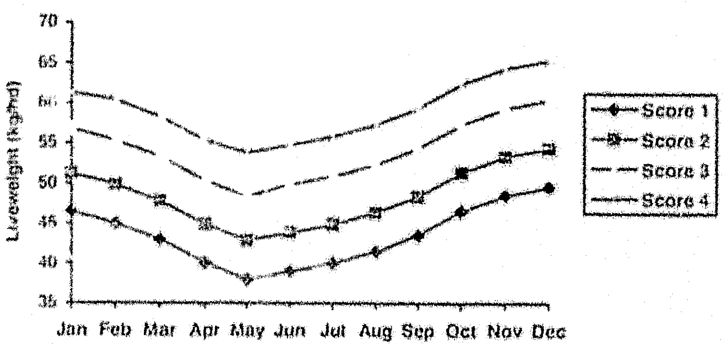
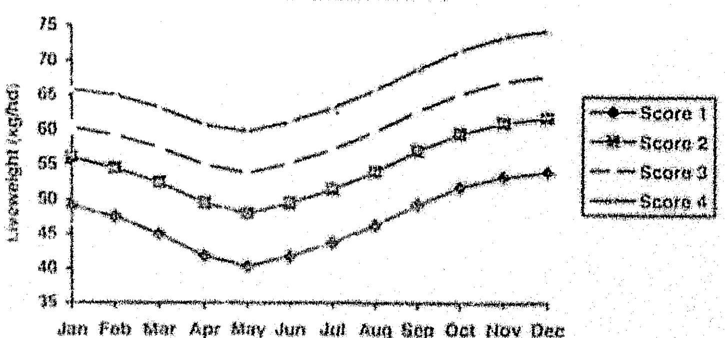


Figure 2b: Wether liveweights at various condition scores



There are over 20 different sheep classes considered in the self-replacing flock in MIDAS. Depending on the relative prices of wool and live trade prices for lamb and young wethers and the husbandry costs associated with each livestock class, various flock structures are profitable options.

The Merredin region is located within the Midlands Statistical Division of Western Australia. In 1994-5 82.7 percent of all wool sold from the Midlands region comprised wool from the 20,21,22 and 23 micron grades in the following proportions 0.19,0.29,0.31 and 0.21. Only 8 percent of wool sold from the region was of 19 micron or less. Table 2 shows the types and proportions of wool produced by three year old wethers subject to various condition score management regimes. The price differentials across micron and condition score groupings were based on price differentials reported in wool sales at Fremantle in October and November in 1995 and include price discounts for tenderness.

Table 2: Assumptions in MIDAS about wool yields, types and prices for three year old wethers as affected by condition score management

Condition Score		Unit	Wethers 3yr
1	Wool cut	kg/hd	5.5
	21 micron yield	%	30
	22 micron yield	%	45
	23 micron yield	%	25
	average wool price	c/kg greasy	316
2	Wool cut	kg/hd	5.8
	21 micron yield	%	25
	22 micron yield	%	45
	23 micron yield	%	30
	average wool price	c/kg greasy	331
3	Wool cut	kg/hd	6
	21 micron yield	%	20
	22 micron yield	%	45
	23 micron yield	%	35
	average wool price	c/kg greasy	329
4	Wool cut	kg/hd	6.1
	21 micron yield	%	15
	22 micron yield	%	50
	23 micron yield	%	35
	average wool price	c/kg greasy	328

The data in table 2 are typical of the assumptions in MIDAS about wool production. In MIDAS it is generally assumed that each livestock class will produce wool that ranges at most across three micron groupings (e.g. 20, 21 and 22 micron). Older sheep produce coarser wool yet have higher wool cuts. Maintaining adult sheep at low condition scores slightly reduces wool cuts yet increases the proportion of finer wool in the clip. However, the finer wool produced under a condition score 1 management regime results in some wool tenderness for which price discounts apply. Hence it is assumed in MIDAS that the various livestock management strategies do affect the quantity, type and price of wool produced by adult classes of sheep. However, because the management strategies are imposed only on adult sheep the type and yields of wool produced by lambs and hoggets are assumed to not be greatly affected by the various management regimes.

Apart from the wool production and nutritional requirements of animals there are other important production assumptions in MIDAS that arise from the condition scores of animals. These relate to lambing percentages, death rates and sale prices of animals. These assumptions are listed in Table 3 for various sheep classes.

Table 3: Assumptions in MIDAS about sale prices, lambing percentages and death rates for various livestock classes as affected by condition score management

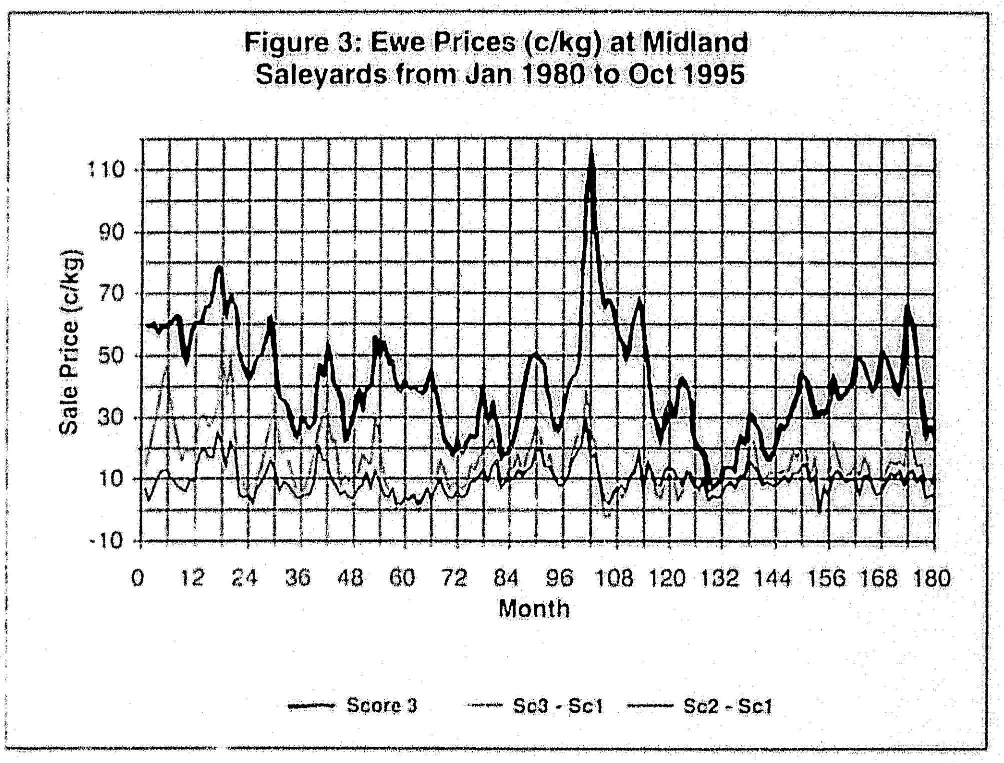
Condition Score		Death rate (%)	Lambing (%)	Sale price[a] ($/hd)
1	Ewes 2 yrs	6	55	8.5
	Ewes 3 yrs	6	60	6.5
	Ewes 4 yrs	6	60	4.5
	Ewes 5 yrs	6	65	3.5
	Lambs 6 months	2		15.5
	Shippers 21months[b]	2.5		17.5
	Wethers 5 yrs	6		10.5
2	Ewes 2 yrs	5	65	10.5
	Ewes 3 yrs	5	70	8.5
	Ewes 4 yrs	5	70	6.5
	Ewes 5 yrs	5	75	5.5
	Lambs 6 months	1		17.5
	Shippers 21months	1.5		19.5
	Wethers 5 yrs	5		12.5
3	Ewes 2 yrs	4.5	75	11.5
	Ewes 3 yrs	4.5	80	9.5
	Ewes 4 yrs	4.5	80	7.5
	Ewes 5 yrs	4.5	85	6.5
	Lambs 6 months	1		18.5
	Shippers 21months	1.5		20.5
	Wethers 5 yrs	4.5		13.5
4	Ewes 2 yrs	4.5	80	11.5
	Ewes 3 yrs	4.5	85	9.5
	Ewes 4 yrs	4.5	85	7.5
	Ewes 5 yrs	4.5	90	6.5
	Lambs 6 months	1		18.5
	Shippers 21months	1.5		20.5
	Wethers 5 yrs	4.5		13.5

[a] These are on farm prices based on livestock prices in October, November and December 1995 at the Midland saleyards and on a historical comparison of prices based on condition scores. Deductions for freight, yarding and agent fees have been applied.
[b] Shippers are generally required to be at or near 50 kg liveweight. Lower prices for shippers usually corresponds to these animals being less than a desirable liveweight.

The data in table 3 indicate that the higher the condition score index the higher the lambing percentage, the higher are saleyard prices and the lower are death rates. The assumed increases in lambing percentage are very conservative given the findings of Pollott and Kilkenny (1976) that a one unit increment in the condition score of ewes at joining was associated with a 29 percent increase in lambs subsequently born. Apart from feed management, the animal husbandry practices (e.g. marking, shearing, drenching) associated with maintaining sheep according to condition scores are assumed to be identical. Hence, the profitability of the sheep enterprise is not altered by differences in management costs (apart from feed costs). It is the production outcomes and output prices that mostly influence the profitability of the sheep enterprise.

Because of the many livestock class options included in MIDAS it is possible for any one of several different self-replacing flock structures to be selected as part of a profit-maximizing strategic farm plan. These flock structures range from ewe-dominant flock structures specialising in lamb production through to wether dominant flock structures that concentrate on wool production.

The price differentials between the various sheep classes in table 3 are based on historical saleyard data. Agriculture Western Australia has maintained since 1980 a record of prices at the Midland saleyards for sheep of various classes and condition scores. For example, figure 3 displays the price differences (in cents per kg dressed weight) since 1980 between score 2 and score 1 ewes with carcass weights less than 19 kg and between score 3 ewes (carcass weights between 19 and 26 kg) and score 1 ewes (carcass weights less than 19 kg). From such data are derived typical price differentials for the various livestock classes and these were applied to saleyard prices as observed in October, November and December in 1995. Where saleyard prices were expressed on a dressed weight basis they were converted to liveweight values, by using typical dress-out percentages. For example, a score 1 15.7 kg carcass equals a 33 kg liveweight animal, a score 2 19 kg carcass equals a 40 kg liveweight animal and a score 3 22.4 kg carcass equals a 47 kg liveweight animal.



Farm Plans and Profits

When livestock management is broadly based on maintaining animals' condition scores how are farm profits and enterprise selection affected ? To provide an answer the MIDAS model was sequentially constrained to select each livestock management regime and the farm plans and profits associated with each regime were then compared and contrasted. The main findings are given in Table 4.

The results in Table 4 show that maintaining adult sheep to be generally in condition score 1 or 4 is far less profitable than maintaining adult sheep in condition score 2 or 3. For example, the profit difference between maintaining sheep in condition score 2 or 3 is small ($478) compared to the profit difference involving management at condition score 2 versus 1 ($5647) or condition score 2 versus 4 ($4840). Maintaining adult sheep at condition score 1 is the least profitable management option. Given the animal welfare concerns associated with maintaining sheep at condition score 1, it follows that profits can be raised and animal welfare concerns reduced if sheep are maintained in condition score 2 or 3. There need be no trade-off between animal welfare and farm profit, given the strategic management of the farm's enterprises and its resources as documented.

Table 4: Summary of farm plans and profits given condition score management of livestock

	Units	Maintaining adult sheep in condition score			
		1	2	3	4
Profit	$'000	5.1	10.8	10.2	6.0
Sheep grazing in winter	dse	3123	3104	2882	2824
Crop area	ha	1500	1500	1500	1500
Cereal area	ha	917	917	917	917
Lupin area	ha	417	417	417	417
Pea area	ha	167	167	167	167
Pasture area	ha	1000	1000	1000	1000
Wool sold	'000 kg	15.0	15.8	15.4	11.7
Ewe lambs sold	no.	0	0	0	128
Wether lambs sold	no	0	0	0	692
Ewe hoggets sold	no.	12	103	145	111
Shippers 21 month	no	0	453	47	0
Shippers 33 month	no	378	57	398	0
CFA ewes	no.	314	343	268	365
Number of ewes	no.	1449	1547	1198	1632
Lupin grain fed	tonnes	35.9	62.0	57.5	56.5
stocking rate	dse/ha pasture	3.12	3.10	2.88	2.82

The market place preferences for score 2 and 3 animals, the price discounts for tender wool and the production offsets (e.g. reduced lambing and higher death rates) that accompany maintaining adult sheep at condition score 1 all combine to ensure that this management regime is far less profitable than those that maintain sheep in condition score 2 or 3. Hence although maintaining adult sheep in condition score 1 reduces the need for grain feeding, allows the stocking rate to be higher and enables more lupin grain to be sold rather than used as supplementary feed these desirable outcomes are offset by lower sale prices of animals, greater death rates, slightly lower wool cuts and lower lambing percentages.

Interestingly, in spite of the range of profits associated with maintaining adult livestock at particular condition scores there are no differences in land use. Optimal land use associated with each livestock management regime is the same. Hence, although allowing sheep to be in condition score 2 or 3 is much more profitable than the other livestock management regimes it is not sufficiently more profitable to trigger land use changes. Across all livestock management regimes pasture production is only optimal on the S1 (acid sands) and S6 (heavy clay) soil classes. Rotation options involving lupins and wheat and wheat and field peas are so profitable on the remaining soil classes that greater change in the profitability of livestock production is needed before these rotations are displaced. Similarly because continuous pasture production on the soil classes S1 and S6 is so profitable, greater reductions in the profitability of the livestock enterprise are necessary before less pasture area is selected on these soils.

Other general findings in table 4 are that as the condition score of adult animals increases then the stocking rate and numbers of animals carried through the autumn and early winter months of feed scarcity decrease. Animals at higher condition scores have greater maintenance and growth requirements because of their greater liveweights. These greater feed requirements restrict the stocking rate for these animals.

The various lambing percentages associated with maintaining ewes at the various condition scores, along with changes in death rates, wool yields, wool types and sale prices of animals I all combine to affect optimal flock structure and stock turn-off as shown in table 4. At condition score 1 low lambing percentages affect the relative profitability of ewes and wethers leading to a more wether dominant flock with fewer ewe hoggets available for sale and wethers being kept until sold as 33 month-old shippers. By contrast at condition score 4 where high lambing percentages are achieved, a ewe-dominant flock is optimal with all livestock, apart from cast-for-age ewes, being sold as lambs or hoggets. At condition score 2 and 3 no animals are sold as lambs. Instead most stock, apart from cast-for-age ewes, are sold as hoggets or 21 or 33 month-old shippers.

Sensitivity Analysis

In this section sensitivity analysis is used to assess the robustness of the finding that the most profitable farm management strategy includes maintaining adult sheep in condition score 2. Further, sensitivity analysis is used to assess the generality of the profit rankings that in ascending order are maintenance of sheep in condition score 1,4,3 then 2. The sensitivity analysis was conducted as an experiment in which the farming system was subject to several price scenarios involving changes in wheat, wool and saleyard prices for animals.

The on-farm wheat price in the standard model was increased and decreased in $20 per tonne increments up to a differential of $60 per tonne. This produced 7 wheat price scenarios where the price changes were -60,-40,-20,0,20,40 and 60 dollars per tonne relative to the standard wheat price. In each livestock management version of the farming system model on-farm prices of animals sold or retained were also increased or decreased in 20 percent increments up to a differential of 60 percent. This provided 7 scenarios for livestock prices. Given that wool prices in the standard model were already at historically low levels, wool prices were decreased in increments of 15 percent to a maximum reduction of 30 percent but were increased up to 60 percent. This generated a set of 7 wool price scenarios.

At combinations of wheat, wool and sheep prices, the profitability of the various livestock management strategies were calculated. Table 5 presents a summary of the profitability rankings of the livestock management strategies. In all scenarios, apart from those involving relatively high sheep prices, the most profitable farm management strategy included maintaining adult sheep in condition score 2. At high sheep prices maintaining adult sheep in condition score 3 was slightly more profitable. At these high prices the profit difference between strategies involving maintaining adult sheep in condition score 3 or 2 was usually less than $2000 whereas the profit difference between strategies involving maintaining adult sheep in condition score 2 or 1 was usually more than $8000.

For all price scenarios reported in Table 5 maintaining adult sheep in condition score 2 was more profitable than maintaining adult sheep in condition score 4 or 1. At low sheep prices or higher wool prices maintaining adult sheep in condition score 1 rather than 4 was slightly more profitable. However, the profit difference was often less than $1000, especially when wool prices were increased by 15, 30 or 45 percent.

Although the results in Table 5 emphasize the profitability of maintaining adult sheep in condition score 2 or 3 rather than 1 or 4, it should be remembered that the differences in farm profits arise not solely through management of livestock condition but also through altering flock size and structure and altering land use. For example, table 6 is a summary of farm plans associated with 3 different price scenarios for wool, given the maintenance of livestock condition scores at different levels.

Table 5: Summary of rankings of the profitability of farm plans given condition score management of livestock and changes in commodity prices [a]

	Wheat price changes ($/tonne)						
Wool price change (%)	-60	-40	-20	0	20	40	60
-30	Y	Y	Y	Y	Y	Y	Y
-15	Y	Y	Y	Y	Y	Y	Y
0	Y	Y	Y	Y	Y	Y	Y
15	N_1	N_1	N_1	N_1	N_1	N_1	N_1
30	N_1	N_1	N_1	N_1	N_1	N_1	N_1
45	N_1	N_1	N_1	N_1	N_1	N_1	N_1
60	N_1	N_1	N_1	N_1	N_1	N_1	N_1
Sheep price change (%)							
-60	N_1	N_1	N_1	N_1	N_1	N_1	N_1
-40	N_1	N_1	N_1	N_1	N_1	Y	Y
-20	N_1	N_1	Y	Y	Y	Y	Y
0	Y	Y	Y	Y	Y	Y	Y
20	Y	Y	Y	Y	Y	Y	Y
40	Y	N_2	N_2	N_2	N_2	N_2	N_2
60	Y	N_2	N_2	N_2	N_2	N_2	N_2

The letter Y indicates that for the stated price scenarios the rankings of livestock management in descending order of profit are to maintain adult sheep in condition score 2,3,4 and 1 respectively.
N_1 indicates that the rankings of livestock management in descending order of profit are to maintain adult sheep in condition score 2,3,1 and 4 respectively.
N_2 indicates that the rankings of livestock management in descending order of profit are to maintain adult sheep in condition score 3,2,4 and 1 respectively.

Results in table 6 show that wool prices have a substantial effect on farm profits and land use, particularly when sheep are maintained at condition scores 2 or 3. Again there is the finding that irrespective of the wool prices considered, maintaining sheep in condition score 2 or 3 remains part of the most profitable farm management strategy. To be expected, as wool prices increase, the area of pasture increases, livestock numbers increase, wool production increases and cereal areas diminish. Flock structures also alter with increases in wool prices. Flocks become more wether dominant with wethers being sold later as 33 month-old shippers or kept until cast for age.

Finally, table 7 presents summaries of optimal farm plans and profits, given two wheat price scenarios and assuming sheep are maintained at different condition scores. Results in table 7 show that wheat prices have a substantial effect on farm profits and land use, across all livestock management regimes. As indicated in previous sensitivity analyses maintaining sheep in condition score 2 or 3 remains part of the most profitable farm management strategy. As wheat prices increase, the area of pasture decreases, livestock numbers decrease, wool production decreases and the area of cereals increases. However, flock structures are almost all unaffected by the change in wheat prices.

Table 6: Summary of farm plans and profits given condition score management of livestock and changes in wool prices

	Percentage change in wool prices	Units	Maintaining adult sheep in condition score			
			1	2	3	4
Profit	-15	$'000	-2.3	2.6	2.3	-0.2
	+15	$'000	12.8	19.5	18.5	12.8
	+30	$'000	21.7	33.9	31.2	21.0
Sheep in winter	-15	dse	3123	3011	2882	2824
	+15	dse	3238	3559	3315	2741
	+30	dse	5241	5959	5254	3173
Wool sold	-15	'000 kg	15.0	15.3	15.4	12.7
	+15	'000 kg	15.5	18.1	17.7	15
	+30	'000 kg	25.1	30.4	28.1	17.4
Main classes of livestock sold	-15		shippers 33 mth	shippers 21 mth	shippers 21&33 mth	lambs & hoggets
	+15		shippers 33 mth	shippers 21&33 mth	shippers 33 mth	shippers 33 mth & cfa wethers
	+30		shippers 33 mth	shippers 21&33 mth	shippers 33 mth	shippers 33 mth & cfa wethers
Pasture area	-15	ha	1000	1000	1000	1000
	+15	ha	1000	1089	1089	1000
	+30	ha	1375	1625	1559	1098
Cereal area	-15	ha	917	917	917	917
	+15	ha	917	857	857	917
	+30	ha	667	500	544	852

Table 7: Summary of farm plans and profits given condition score management of livestock and changes in wheat prices

	Change in wheat prices ($/tonne)	Units	Maintaining adult sheep in condition score			
			1	2	3	4
Profit	-20	$'000	-23.9	-14.4	-15.6	-23.0
	+20	$'000	36.5	42.1	41.5	37.4
Sheep in winter	-20	dse	4036	5959	5477	3649
	+20	dse	3123	3104	2882	2824
Wool sold	-20	'000 kg	19.4	30.4	29.2	16.4
	+20	'000 kg	15.0	15.8	15.4	12.7
Main classes of livestock sold	-20		shippers 33 mth	shippers 21&33 mth	shippers 33 mth	lambs&hoggets
	+20		shippers 33 mth	shippers 21&33 mth	shippers 21&33 mth	lambs&hoggets
Pasture area	-20	ha	1250	1625	1625	1250
	+20	ha	1000	1000	1000	1000
Cereal area	-20	ha	750	500	500	750
	+20	ha	956	946	946	978

Limitations

The preceding analyses assume that it is technically feasible and managerially inexpensive to ensure adult classes of sheep are maintained at particular condition scores. In practice, the amount and quality of feed on offer to animals varies throughout a production period. Hence, frequent monitoring and assessment of sheep condition in the flocks held on various paddocks across the farm would be necessary to ensure maintenance of condition scores. Such monitoring and assessment is obviously not costless in time or money and requires the farmer to be skilled at condition score appraisal. The fact that most farmers avoid such intensity in the monitoring of animals' condition scores is perhaps an indication that the returns to such a style of sheep management are acknowledged or perceived to be inadequate.

The foregoing analyses estimate the financial benefits to the producer of ensuring adult sheep are maintained at particular condition scores and the main conclusion is that it is profitable to maintain sheep in condition score 2 or 3. However, there are likely to be other benefits experienced by producers and consumers not incorporated in the analyses. McInerney (1993) for example suggests that the process of animal production can result in negative externalities of poor animal welfare which are not fully valued in final good markets and can act as hidden costs. He points out that this is a classic free good situation and as such, animal welfare is over-exploited. This argument that animal welfare is often a negative externality of livestock production is supported by Bennett (1995). A corollary of this argument is that prices paid for livestock may not fully reflect the negative externality that consumers would experience if they knew the meat they were consuming came from animals in condition score 1. Conversely, some consumers would be willing to pay a premium for meat known to come from animals only exposed to condition score 3 management. Hence, from a wider social perspective the net benefits of [illegible]ining sheep in condition score 2,3 and 4 may be greater than the farm profit comparison suggest a[illegible]e net benefits of leaving adult sheep in condition score 1 may be far less than the farm profit comparison suggests.

Although the preceding results imply that maintenance of adult sheep in condition score 1 is less profitable than other forms of livestock management, the results cannot support the suggestion that it is always profitable to avoid placing sheep in condition score 1. It may well be profitable in some circumstances for some farmers to allow some of their sheep flock to be temporarily in condition score 1[1]. For example, the MIDAS model assumes an average production year. However, during drought that is not described by the MIDAS model it may be profitable for farmers to maintain sheep at condition score 1 and thereby preserve their investment in the genetic worth of their flock. In short rather than sell off much of the flock for the sake of maintaining remaining stock in condition score 3, it may be more profitable in the medium or long run to maintain more sheep at a lower condition score. Further, although the liveweight patterns across a production year are typical of those observed in the field, it could be that liveweight losses (and hence changes in condition scores) greater than those assumed in the analyses might be more profitable. That is, it may be more profitable for sheep to vary in their condition scores within a production year to a greater extent than has been assumed in the analyses.

Lastly, the management of the farm's resources in MIDAS is based on maximization of expected profit subject to several physical and other behavioural constraints. It could be that inclusion of weather-year variation, price variance and tactical and risk averse management (Kingwell *et al.*, 1992, 1993; Kingwell, 1994) may generate different conclusions about the optimality of maintaining adult sheep in condition score 2 or 3.

Conclusion

This paper compares and contrasts various sheep management regimes that maintain adult sheep at different condition sco[illegible]. For example, sheep maintained at condition score 1 are mal-nourished and are liable to be affected by heat or cold stress. Legitimate concerns could be raised about the welfare of these animals. By contrast, sheep maintained at condition score 3 or 4 are well-nourished with ample but not excessive body fat and are well-equipped to withstand their environmental conditions.

[1] This includes a loss of liveweight in autumn

Does providing adequate qualities and quantities of feed to sheep to ensure welfare concerns are abated necessarily reduce farm profits by increasing feeding costs ?

Using a representative farm model that emphasises the biology and financial characteristics of a broadacre farming system, results in this paper suggest that farm profits are actually increased by avoiding management strategies that maintain sheep in condition score 1. Maintaining adult sheep in condition score 2 or 3 is shown to be far more profitable than maintaining adult sheep in condition score 1 or 4. This finding is subject to sensitivity analysis in which wool, wheat and sheep saleyard prices are all varied. The finding remains robust that maintaining adult sheep in condition score 2 or 3 is far more profitable than maintaining adult sheep in condition score 1 or 4. A practical managerial inference is that the profitable strategic management of sheep is likely to involve maintaining sheep in condition score 2 or 3, thereby lessening social concern over the welfare of these sheep. The results suggest that there need not necessarily be a trade-off between animal welfare and farm profit.

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