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An Evaluation of the Impact of Long-range Climate Forecasting on the Physical and Financial Performance of Wool-producing Enterprises in Victoria

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Abstract

Improved climate forecasting has the potential to increase the ability of farm managers to cope with a variable climate. In this study a simulation model of a breeding ewe flock was used to make a preliminary assessment of the value of climate forecasting for wool-producing enterprises in Victoria. Stocking and selling policies were modified in response to long-range forecasts of weather conditions. The effects on pasture cover, sheep welfare and financial returns were compared with those of a traditional management policy for a period of 25 years. These comparisons were made at two locations, Hamilton and Rutherglen, and at two stocking rates. The effects of different levels of accuracy of the weather forecast on the value of the changes in stocking and selling policies were also evaluated.

Altering the stocking and selling policies using an accurate forecast of seasonal conditions resulted in a reduction in the death rate of adult ewes and their progeny. Timely action when adverse conditions were imminent resulted in an increase in both pasture cover during autumn and winter and minimum liveweight of the sheep. Gross returns were increased on average by more than 5%. Much of this increase was contributed by higher wool returns associated with the increase in size of the flock during favourable conditions. Expenditure on sheep purchases was lower for the traditionally managed farms; however, knowledge of forthcoming conditions did allow stock numbers to be reduced before pasture reserves were depleted in poor seasons which in turn reduced the requirement for supplementary feed. The total cash costs tended to be lower on the traditionally managed farm, but this difference was not significant. Both the cash operating surplus and net cash income were significantly increased by altering stocking and selling policies using an accurate forecast of seasonal conditions at Hamilton, but, although the same trends were evident, the effect of using the forecast at Rutherglen was not significant.

Where the forecast was accurate in only 8 years in 10 or 6 years in 10, the benefits of altering the stocking and selling policies were reduced, but even at the lower level of accuracy the average cash operating surplus for the 25 years of the analysis was higher than that achieved using the traditional management regime. However, in individual years, inappropriate policies adopted due to an incorrect forecast resulted in reductions in financial returns of up to 64%.

Accurate forecasts can improve land care and animal welfare by changing pasture and animal management, particularly by reducing stock numbers. However, since the profitability of sheep enterprises in Victoria is highly dependent on the choice of stocking rate, recommendations to reduce stock numbers without considering the financial viability of sheep enterprises may go unheeded. Hence, in the short-term at least, it can be difficult to achieve improvements in land care and animal welfare while at the same time maintaining profitability.

This study indicated that the financial benefits for wool producers of reliable seasonal outlooks in southern Australia are probably substantially less than generally anticipated, at least for the strategies investigated. Furthermore, the accuracy of seasonal forecasting in southern Australia is such that the benefits from correct forecasts can be partly offset in

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other years from decisions which have been made on the basis of incorrect forecasts. The study also highlighted a number of important issues that need to be considered in evaluating climate forecasts.

Keywords: climate forecasting, drought, farm management, simulation modelling.

Introduction

The productivity and profitability of sheep farms in southern Australia are greatly reduced in drought years. Under such conditions it is considered good practice to retain only essential breeding stock so that pasture deterioration is not exacerbated and excessive soil erosion does not occur. Disposing of stock at a reasonable price can also be a problem if they are not in good condition. Surplus stock will either be slaughtered, sold or agisted interstate, often with little or no financial return to the farmer. High levels of supplementary feeding for sheep retained on the property are likely to be needed. However, feeding supplements to sheep prior to sale in order to improve their condition can also be unprofitable.

It can therefore be difficult and often costly for farmers to respond quickly to changing seasonal conditions. Stock can be purchased to take advantage of good conditions, but they can also be expensive, particularly if bought out-of-season. Young stock bred on the farm can be used to boost adult stock numbers, but the timing of introduction of replacements depends on the time of lambing.

The gap that can exist between the cost of purchase and the store stock price erodes part if not all of the benefit of adapting stock numbers to changing seasonal conditions. Also, buying and selling stock in order to adapt to seasonal conditions can increase exposure to fluctuations in livestock prices induced by factors other than the changes in seasonal conditions. As Arnold and Bennett (1975) have shown, the level of profitability is likely to be greater in the long-term from adopting a near-constant, near-optimal stocking rate, than by buying in stock in good seasons and selling stock in poor seasons.

Good farm business management requires planning in anticipation of both favourable and drought years (Blackburn *et al.* 1992). This more self-reliant approach to farm and drought management is particularly important given the highly variable climate that typifies much of Australia. The way in which farms are managed during drought is often critical to determining whether such production systems are physically, biologically and financially sustainable in the long-term.

Aids to more self-reliant drought and farm management are currently being developed. These include improved long-range climate forecasting systems, applying models to estimate temporal and spatial changes in soil moisture and vegetation cover, cloud and terrestrial monitoring by remote sensing, and decision support systems to aid on-farm decision making (White *et al.* 1993).

Improvements in the reliability of seasonal forecasts offer the opportunity for stock numbers to be reduced when there is an increased probability of drought, to the benefit of the soil and vegetation (Freebairn 1983; McKeon and White 1992). The environmental and financial stresses from responding too late can therefore be diminished. Reliable forecasts also give farmers the opportunity to increase their stocking rates in anticipation of particularly favourable seasons. However, no forecast is 100% reliable, so that the risk and consequences of incorrect forecasts must be incorporated into the farm's strategic plan (White 1993). Contingency plans should therefore be developed.

In this study we used a simulation model of a breeding ewe flock (DYNAMOF, Bowman *et al.* 1989*a*, 1993), that has been rigorously tested over a number of years using data from northern and western Victoria. The model was used to analyse and compare a number of management strategies so that the value of long-range weather forecasts to wool producers could be assessed.

Stocking and selling policies of a wool-producing enterprise were modified in response to long-range forecasts of weather conditions. The effects on pasture cover, sheep welfare and financial returns were compared with those of a traditional management policy. The effects of different levels of accuracy of the weather forecast on the value of the changes in stocking and selling policies were also evaluated.

Methods

The comparisons between traditional farm management planning and that based on seasonal forecasts were conducted using the aforementioned simulation model of a breeding ewe flock. The model and the input data required are described in some detail by White *et al.* (1983) and Bowman *et al.* (1989*a*, 1993), so that only the relevant components are summarized here.

Details of the Simulated Farms

In a series of experimental runs of the breeding ewe model, the farm production and income were simulated on a weekly basis for a period of 25 consecutive years using historical climatic and financial data. A farm area of 500 ha was chosen with the pastures continuously grazed by a self-replacing flock of Peppin Merino ewes and wethers. The ewes lambed in late April and May and had a weaning rate of about 82 lambs per 100 ewes mated. The ewes produced an average of 4·3 kg of clean wool per head per year, of 23 μm diameter.

Location

Two sites were chosen for investigation: Hamilton in western Victoria and Rutherglen in the north-east. Farms near Hamilton are characterized by perennial ryegrass (*Lolium perenne*) and subterranean clover (*Trifolium subterraneum*) pastures and an annual rainfall of 700 mm. Rutherglen is dominated by annual ryegrass (*Lolium rigidum*) and subterranean clover pastures and 555 mm rain per annum. Meteorological data collected at the Pastoral Research Institute, Hamilton, and the Rutherglen Research Institute, Rutherglen, between January 1965 and June 1989 were used to define the climatic conditions experienced by the simulated farms. The 25 year sequence of data provided a wide range of seasonal conditions, including severe droughts in 1967 and 1982.

Description of the Investigations

Two analyses were undertaken for each location. In the first the physical and financial performance of the farms under a traditional management policy were predicted for each financial year from 1965/66 to 1988/89. In a subsequent run of the model the stocking and selling policies of the enterprise were modified each year based on the weather conditions to be experienced over the following 12 months. The benefits accruing from 'perfect knowledge' of subsequent seasonal conditions were then investigated by comparing the predicted production and income for these two management regimes. Emphasis was placed on examining the effects on pasture cover, sheep liveweight and financial returns. For convenience, these two management regimes were termed 'traditional' and 'perfect knowledge' respectively.

The number of sheep in the traditionally managed flock was chosen such that the average stocking rate for the period 1965 to 1989 was optimum, where the optimum stocking rate was defined as that which produced the maximum net cash income over the 25 years. The number of sheep in the 'perfect knowledge' flock was chosen such that the average flock stocking pressure over the 25 years of the analysis was the same as for the traditional flock (see Bowman *et al.* 1989*b*, p. 294, for details of the calculation of stocking pressure). Given that risk-averse farmers may not be prepared to run their flocks at the optimum stocking rate, a second series of runs was undertaken where the stocking rate of the traditional flock was 80% of the optimum. This stocking rate was termed conservative.

In the second set of analyses the effect of different levels of accuracy of the weather forecast on the value of the changes in stocking and selling policies was evaluated. Two levels of accuracy were investigated at the conservative stocking rate: forecast correct in 8 years in 10 and correct in 6 years in 10. The years deemed to have an incorrect forecast were chosen at random. The stocking and selling policies which would have been adopted given perfect knowledge were randomly exchanged between years with an incorrect forecast. Thus the total range of stocking and selling policies developed using perfect knowledge of the seasonal conditions remained unchanged, but in the years deemed to have incorrect forecasts the policies were reallocated. A total of 10 runs was investigated for each level of accuracy.

Stocking and Selling Policy

An accurate long-range forecast of weather conditions provides farmers with the opportunity to adjust stocking and selling policies according to changing conditions. Thus, stock numbers can safely be increased during a sustained period of favourable seasonal conditions without risking soil and pasture damage or animal welfare. Similarly, if there is adequate warning of adverse seasonal conditions, then stock numbers can be reduced before damage occurs to the soil and pasture and before the condition of the sheep deteriorates to the extent that their sale price is severely penalized.

The changes in stocking rate required in this study to adapt to variations in seasonal conditions were achieved by varying the number of adult wethers on the farm. The wethers thus acted as a buffer flock that could be expanded during periods of favourable conditions in order to generate additional income. The size of this flock could also be reduced during adverse conditions, thereby protecting the more valuable breeding ewes and replacement stock.

In the traditionally managed flocks, adult wethers represented 30% of the total number of adult stock. This ratio was changed only in very poor years when a substantial proportion of the adult wethers was sold at a special sale in order to reduce the impact on the soil and pasture and animal welfare. Special sales of wethers occurred earlier for the perfect knowledge flocks given forewarning of the adverse conditions. The number needing to be sold also tended to be smaller due to the more timely response. The prices received at these sales were based on the weight of the sheep and prices for different classes of stock received in Victorian saleyards (Bowman *et al.* 1989*a*).

The proportion of wethers in perfect knowledge flocks was altered each year in anticipation of changing climatic conditions by varying the number of wethers sold in spring. With the exception of years in which special sales occurred, the proportion of adult wethers varied from 20 to 50% of the total number of adult stock. It was assumed that the farm manager had perfect knowledge of climatic conditions over the following 12 months when deciding how many wethers to sell. In order to determine the optimum size of the wether flock for each year in the analysis, the simulation model was used to predict the effect of daily climatic events for a given year on the quantity and quality of pasture produced and on animal performance. An iterative procedure was employed which sought to maximize mean net cash income subject to the constraint that the average stocking pressure for all years was the same as for the traditionally managed flocks. In the first iteration, daily climatic records for a given calendar year were used by the model to predict pasture production and animal performance, using the management settings for the traditionally managed flocks. In subsequent iterations the proportion of wethers present each year was adjusted according to the degree to which key pasture and animal performance indicators were above or below average.

Supplementary Feeding

Supplementary feed was provided using the detailed set of criteria described by Bowman *et al.* (1989*a*) and Bowman (1989) with the aim of ensuring the survival of adult sheep and their progeny. These criteria take account of the changing feed requirements of each class of sheep and the effect of seasonal conditions on their body condition. The feeding strategy employed was, therefore, sensitive to variations in climatic conditions and changes in management. However, supplementary feed was not used to improve the body condition of adult sheep as previous studies (White and Bowman 1987; Bowman 1989; Bowman *et al.* 1989*b*) had indicated that this strategy would not be profitable in a wool-producing enterprise.

Results

Analysis 1: Traditional Management Versus Perfect Knowledge of Seasonal Conditions

Physical and Financial Performance of the Hamilton Farm

Table 1 presents the financial returns predicted for the simulated farm at Hamilton. At the conservative stocking rate, altering stocking and selling policies using knowledge of seasonal conditions over the coming 12 months resulted in a 6·3% increase in gross returns. Much of this increase was contributed by higher wool returns associated with the increase in size of the wether flock during favourable conditions. There was also a trend towards higher returns from livestock sales, but this difference was not significant.

Table 1. A comparison of the effect of the traditional and perfect knowledge management regimes on the financial costs and returns for the Hamilton farm at the conservative and optimum stocking rates

Means within rows followed by the same letter are not significantly different ($P > 0 \cdot 05$)

	Stocking rate			
	Conservative		Optimum	
	Traditional[A]	Perfect knowledge[A]	Traditional[A]	Perfect knowledge[A]
Returns ($)				
Wool	49070	52680	59900	64100
Livestock sales	17140 q	17780 q	20680 r	21440 r
Interest	1510 q	1520 qr	1500 q	1550 r
Gross returns	67720	71980	82080	87090
Costs ($)				
Enterprise	20130 q	20200 q	25060 r	25080 r
Sheep purchases	20 q	1090 r	100 q	1400 r
Supplementary feed	2290	2120	3280	2930
Labour and storage	2640	2990	4970	5370
Total cash costs	25080 q	26410 q	33410 r	34780 r
Cash operating surplus	42640	45580	48670	52310
Net cash income	13600	15030 q	15040 q	16810

[A] Mean for the 1965/66 to 1988/89 financial years.

Enterprise costs for the two management regimes were similar. Expenditure on sheep purchases was lower for the traditionally managed farms as sheep were only purchased after a drought in order to re-establish flock numbers. By comparison, stock were purchased more frequently on the farms using knowledge of forthcoming seasonal conditions in order to take advantage of favourable conditions. The increase in stock numbers during good seasons also led to a greater requirement for casual labour than for the traditionally managed farm. However, knowledge of forthcoming conditions did allow stock numbers to be reduced before pasture reserves were depleted in poor seasons which in turn reduced the requirement for supplementary feed. The total cash costs tended to be lower on the traditionally managed farm, but this difference was not significant. Both the cash operating surplus and net cash income were significantly increased by altering stocking and selling policies using perfect knowledge of seasonal conditions.

Similar differences in costs and returns between the management regimes were also evident at the optimum stocking rate. Adapting the stocking and selling policies to changing seasonal conditions resulted in a 7·5% increase in cash operating surplus when compared to the traditional management regime.

In order to gain some insight into the effect of the management regimes on ground cover, the minimum amount of pasture available in each season of the year was recorded. The average results for the full 25 years of the analysis (Table 2) suggest that there was little difference between the management regimes. However, important differences were observed in individual years (Table 3). Forewarning of the 1967 and 1982 droughts and the very poor conditions in 1972 allowed for timely adjustment of stocking rate in order to minimize the impact of the adverse conditions. As a result, the traditionally managed farms were predicted to have on average of 18% less pasture available in the autumn and winter of these years. Conversely, advance knowledge of periods of favourable conditions allowed stocking rates to be increased, and hence the traditionally managed farms had more pasture available in good years.

Table 2. A comparison of the average effect of the traditional and perfect knowledge management regimes on components of the physical performance of the Hamilton farm at the conservative and optimum stocking rates

Means within rows followed by the same letter are not significantly different ($P > 0{\cdot}05$)

	Stocking rate			
	Conservative		Optimum	
	Traditional[A]	Perfect knowledge[A]	Traditional[A]	Perfect knowledge[A]
	Minimum amount of pasture available (kg ha^{-1})			
Summer	3846 q	3833 q	3105 r	3090 r
Autumn	2279 q	2262 q	1700 r	1691 r
Winter	1723 q	1686 q	1228 r	1186 r
Spring	2284 q	2202 q	1680 r	1608 r
	Minimum flock liveweight within a year (kg)			
Adult ewes	49·2 q	49·4 q	48·6 r	49·0 qr
Adult wethers	52·1 q	53·7	49·8	51·0 q
	Total number of deaths (sheep year^{-1})			
Adult ewes	50	47	65	61
Adult wethers	12 q	14 q	22 r	22 r
Ewe replacements	27	25	35	32
Wether replacements	35	32	49	43

[A] Mean for the 1965/66 to 1988/89 financial years.

Similar trends were evident for the minimum liveweight of adult ewes and wethers (Tables 2 and 3). Timely action when adverse conditions were imminent resulted in the minimum liveweight of the sheep being higher. The death rates of adult ewes and replacement stock were reduced as a consequence of stocking and selling policies given knowledge of future seasonal conditions. The same differences in long-term average death rates were not evident for the adult wethers

Table 3. A comparison of the effect in very poor years of the traditional and perfect knowledge management regimes on components of the physical performance of the Hamilton farm at the conservative and optimum stocking rates

	Stocking rate			
	Conservative		Optimum	
	Traditional	Perfect knowledge	Traditional	Perfect knowledge
Minimum amount of pasture available in autumn (kg ha^{-1})				
1967	2471	3081	1644	2384
1972	1674	1760	1238	1318
1982	2248	2811	1568	2202
Minimum flock liveweight (kg)				
1967				
Adult ewes	45·5	46·7	45·1	45·2
Adult wethers	40·3	44·7	39·0	42·6
1972				
Adult ewes	49·9	51·0	46·4	48·2
Adult wethers	53·8	54·2	48·2	50·6
1982				
Adult ewes	45·0	46·7	41·9	44·5
Adult wethers	39·9	42·9	37·4	39·7
Total number of deaths (sheep year^{-1})				
1967				
Adult ewes	72	64	90	86
Adult wethers	12	7	43	10
Ewe replacements	37	34	52	45
Wether replacements	60	55	93	72
1972				
Adult ewes	51	48	67	62
Adult wethers	13	17	46	39
Ewe replacements	22	21	31	28
Wether replacements	28	26	42	37
1982				
Adult ewes	71	61	103	86
Adult wethers	28	9	82	16
Ewe replacements	36	31	51	45
Wether replacements	49	43	69	59

because they received a lower priority than the adult ewes and replacement stock in the allocation of land area.

Physical and financial performance of the Rutherglen farm

The advantages of adapting stocking and selling policies to changes in seasonal conditions were also evident in the results for the Rutherglen farm (Table 4). The income from both wool and gross returns was significantly increased. Expenditure on sheep purchases was again lower for the traditional management regime and supplementary feed costs were higher. Unlike the Hamilton farm, labour and storage costs did not differ significantly between the two regimes, but the trend towards lower costs for traditional management was the same. The differences in cash operating surplus and net cash income between the management regimes tended to be more variable for the Rutherglen farm than for the Hamilton farm and, although there were strong trends towards lower income for the traditional management, the differences were not significant.

Table 4. A comparison of the effect of the traditional and perfect knowledge management regimes on the financial costs and returns for the Rutherglen farm at the conservative and optimum stocking rates

Means within rows followed by the same letter are not significantly different ($P > 0{\cdot}05$)

	Stocking rate			
	Conservative		Optimum	
	Traditional[A]	Perfect knowledge[A]	Traditional[A]	Perfect knowledge[A]
Returns ($)				
Wool	30030	31790	36310	38380
Livestock sales	9990 q	10340 q	11750 r	12180 r
Interest	1250 q	1250 q	1330 r	1320 r
Gross returns	41270	43380	49390	51880
Costs ($)				
Enterprise	13040 q	13010 q	16170 r	16110 r
Sheep purchases	20 q	910 r	50 q	1180 r
Supplementary feed	1900	1750	2550	2300
Labour and storage	440 q	460 q	1090 r	1190 r
Total cash costs	15400 q	16130 q	19860 r	20780 r
Cash operating surplus	25870 q	27250 q	29530 r	31100 r
Net cash income	7900 q	8590 q	9320 r	10060 r

[A] Mean for the 1965/66 to 1988/89 financial years.

The effects of the management regimes on pasture cover, sheep liveweight and deaths for the Rutherglen farm were similar to the Hamilton farm, both in the long-term (Table 5) and in individual years (Table 6). In very poor years the change in stocking and selling policies using perfect knowledge resulted in an increase in pasture availability, sheep liveweight and an overall reduction in sheep deaths when compared to traditional management. The lower pasture availability in poor seasons was again offset by higher pasture availability in good seasons such that there was no difference between the management regimes in the long-term. Over the 25 years of the analysis, a consistent increase in wether liveweights, and a reduced number of deaths of adult ewes and replacement stock, were achieved using perfect knowledge of seasonal conditions.

Analysis 2: Effect of Different Levels of Accuracy of the Weather Forecast

Long-term financial performance

The effect of two levels of accuracy of the weather forecast on the long-term financial performance of the farms is shown in Table 7. At each level of accuracy, 10 different sequences of years with an incorrect forecast were evaluated. The mean cash operating surplus for the full period from 1965 to 1989 was then compared to the result achieved using traditional management and perfect knowledge. The average result for the 10 sequences decreased as the accuracy of the forecast was decreased, but even where the forecast was only accurate in 6 years in 10, the average result was still greater than that achieved using the traditional management regime. Individual sequences of years with an incorrect forecast did, however, result in a greater reduction in long-term financial performance. The worst result was recorded for the Rutherglen farm at the lower level of accuracy where the mean cash operating surplus for one sequence was less than that predicted for the traditional management regime.

On the other hand, the long-term financial performance for some sequences was greater than that achieved using perfect knowledge of seasonal conditions. This was associated with favourable fluctuations in the price of wool and livestock which negated the detrimental effects of an incorrect weather forecast. For example, an incorrect forecast in 1973 led to a higher stocking rate than that chosen given perfect knowledge of the seasonal conditions. This in turn reduced pasture and sheep performance. However, wool prices in 1973 were very high which, in combination with the increased stocking rate and hence increased wool production, resulted in a substantial increase in wool returns. Similarly, although an inappropriate buying and selling policy led to reduced sheep performance due to overstocking in a poor season and reduced income due to understocking in a good season, this could at least be partly offset by a low price for the stock purchased in the poor season when combined with a higher price for the stock sold in the good season.

Financial performance in individual years

Although the long-term financial performance at the two levels of forecast accuracy was greater than for the traditional management regime, inappropriate stocking and selling policies adopted due to an incorrect forecast resulted in substantial reductions in financial returns in individual years. Table 8 shows the cash operating surplus for the financial year where an incorrect forecast caused the greatest reduction in the financial performance compared with that achieved given perfect knowledge. The effect of the incorrect forecast on financial returns was substantial. For example, at the lower level of forecast accuracy

Table 5. A comparison of the average effect of the traditional and perfect knowledge management regimes on components of the physical performance of the Rutherglen farm at the conservative and optimum stocking rates

Means within rows followed by the same letter are not significantly different ($P > 0 \cdot 05$)

	Stocking rate			
	Conservative		Optimum	
	Traditional[A]	Perfect knowledge[A]	Traditional[A]	Perfect knowledge[A]
	Minimum amount of pasture available (kg ha^{-1})			
Summer	3101 q	3078 q	2679 r	2653 r
Autumn	2106 q	2081 q	1753 r	1727 r
Winter	1707	1654	1365 q	1317 q
Spring	2202 q	2171 q	1841 r	1804 r
	Minimum flock liveweight within a year (kg)			
Adult ewes	47·2 q	47·0 q	46·5 r	46·4 r
Adult wethers	49·3 q	50·9	47·6	49·5 q
	Total number of deaths (sheep year^{-1})			
Adult ewes	38	35	50	46
Adult wethers	10 q	14 q	16 r	20 r
Ewe replacements	21	19	30	27
Wether replacements	29	26	43	39

[A] Mean for the 1965/66 to 1988/89 financial years.

Table 6. A comparison of the effect in very poor years of the traditional and perfect knowledge management regimes on components of the physical performance of the Rutherglen farm at the conservative and optimum stocking rates

	Stocking rate			
	Conservative		Optimum	
	Traditional	Perfect knowledge	Traditional	Perfect knowledge
	Minimum amount of pasture available in autumn (kg ha^{-1})			
1967	2573	2789	2077	2363
1976	2134	2223	1701	1814
1982	2517	2795	2160	2515
	Minimum flock liveweight (kg)			
1967				
Adult ewes	44·7	44·9	44·5	44·5
Adult wethers	37·4	42·4	36·8	41·8
1976				
Adult ewes	45·1	45·3	44·2	44·4
Adult wethers	49·3	49·7	47·4	48·4
1982				
Adult ewes	46·8	47·0	45·5	46·2
Adult wethers	43·6	48·5	37·7	46·1
	Total number of deaths (sheep year^{-1})			
1967				
Adult ewes	46	43	58	53
Adult wethers	9	13	12	18
Ewe replacements	34	31	49	40
Wether replacements	65	57	95	80
1976				
Adult ewes	45	41	60	55
Adult wethers	12	17	20	26
Ewe replacements	22	20	31	28
Wether replacements	31	29	54	46
1982				
Adult ewes	31	29	41	36
Adult wethers	9	4	16	5
Ewe replacements	21	18	31	24
Wether replacements	22	20	33	27

the cash operating surplus for the Rutherglen farm in 1980/81 was 36% of that achieved using traditional management and 26% of that achieved using perfect knowledge. The largest reductions in operating surplus were usually associated with overstocking in poor seasons. Adverse trends in livestock prices also tended to exacerbate problems caused by inappropriate stocking and selling policies.

Discussion

Improved climate forecasting has the potential to increase the ability of farmers to handle a variable climate. The value of climate forecasting has previously been investigated with respect to crop production, particularly with respect to decisions on whether or not to sow, or to irrigate a crop (Clewett *et al.* 1991; Hammer *et al.* 1991; Russell 1991; Mazzocco *et al.* 1992).

In this study we made a preliminary assessment of the value of climate forecasting for pasture-sheep production systems. Previous studies by Bowman

Table 7. The effect of different levels of accuracy of the weather forecast on the cash operating surplus for the Hamilton and Rutherglen farms ($)

	Hamilton	Rutherglen
Traditional management	42640	25870
Perfect knowledge	45580	27250
	Forecast accurate in 8 years in 10[A]	
Average	45030	27130
Lowest	43410	26550
Highest	45800	27510
	Forecast accurate in 6 years in 10[A]	
Average	44690	26760
Lowest	43170	25570
Highest	45750	27400

[A] Results for 10 runs of the model from 1965 to 1989 where the years with an incorrect forecast were chosen at random.

Table 8. Cash operating surplus for the financial year where an incorrect forecast caused the greatest reduction in the financial performance of the Hamilton and Rutherglen farms ($)

	Hamilton	Rutherglen
	Forecast accurate in 8 years in 10[A]	
Financial year	1984/85	1983/84
Traditional management	51710	25580
Perfect knowledge	73650	34370
With incorrect forecast	40310	16840
	Forecast accurate in 6 years in 10[A]	
Financial year	1987/88	1980/81
Traditional management	86460	20340
Perfect knowledge	113230	28280
With incorrect forecast	60990	7270

[A] Results for 10 runs of the model from 1965 to 1989 where the years with an incorrect forecast were chosen at random.

(1989) and Bowman *et al.* (1989*b*) showed that the potential value of a technology may be substantially reduced because there are conflicting demands within a farm on the finite set of resources available to achieve improvements in production and profit. They also showed that substantial financial returns to technological inputs were often likely to be unattainable in most of Australia's extensive wool production systems. Similar conclusions were reached in this study.

Physical Impacts

The likely benefits from having perfect seasonal knowledge were examined first. An important effect of partial destocking on the basis of such knowledge was having a greater minimum amount of pasture cover in autumn in very dry years. This is consistent with the prevailing view, endorsed in the national policies on drought and ecologically sustainable development, that land should be destocked as soon as possible in the event of a drought. Failure to destock will often lead to increased exposure of bare soil (White *et al.* 1980) and increased risk of soil erosion (Morley and Daniel 1992). Seasonal forecasts can therefore assist in anticipating drought and minimizing the risk of soil and vegetation degradation (McKeon and White 1992).

Associated with the extra pasture cover in these dry seasons was an increase in minimum flock weights and a decrease in sheep deaths. The importance of this differed between seasons and locations. There were also financial benefits to the farmers from accurate seasonal outlooks in that the need for supplementary feed was greatly reduced. The significance of these effects increases as one moves from a conservative to a near-optimum, in terms of profit maximization, stocking rate. The benefits in terms of better sheep condition and fewer deaths should be viewed in terms of partially allaying community concerns on animal welfare (Miller 1985; SCAW 1989).

Improvement in land care and animal welfare can be achieved by changing pasture and animal management, particularly by reducing stock numbers. However, since the profitability of sheep enterprises in Victoria is highly dependent on the choice of stocking rate (Morley 1981; White 1987), recommendations to reduce stock numbers without considering the financial viability of sheep enterprises may go unheeded. Hence, in the short-term at least, it can be difficult to achieve improvements in land care and animal welfare while at the same time maintaining profitability in real money terms (i.e. corrected for inflation). This requires an ongoing trend of increasing profitability in nominal terms, consistent with increasing productivity and cost-effectiveness.

Financial Returns

This study indicated that the long-term financial benefits for wool producers of reliable seasonal outlooks in southern Australia are probably substantially less than generally anticipated, at least for the strategies investigated. Furthermore, the accuracy of seasonal forecasting in southern Australia is currently significantly less than perfect knowledge, so that benefits from correct forecasts can be largely offset in other years from decisions which have been made on the basis of incorrect forecasts. This was recognized and accounted for by our analyses using probabilities that either 6 out of 10 or 8 out of 10 forecasts would be accurate, these showing that management on the basis of forecast information would still be profitable. Obviously, the high variance in financial returns associated with only 6 out of 10 forecasts being accurate means that there would be an unacceptable financial risk for farm managers with significant debts being over-reliant on such forecasts for decision making.

The study also raised the following issues that need to be considered in evaluating climate forecasts.

Costs of responding to changes in climatic conditions

When seasonal conditions are poor it is often desirable to reduce stock numbers. However, under such conditions the supply of stock to the market is likely to be high, the demand low and the price reduced. In good seasonal conditions the demand is likely to be high, supply low and the price increased. The gap which can exist between the cost of the sheep when purchased and the price when sold erodes part of the benefit of adapting stock numbers to changing seasonal conditions. Also, buying and selling stock in order to adapt to seasonal conditions can increase exposure to fluctuations in livestock prices induced by factors other than the changes in seasonal conditions. It can also increase the risk of contracting diseases such as footrot and parasites.

In this study the principle means of responding to poor climatic conditions was to reduce the size of the wether flock. This is a common practice for commercial wool-producing flocks where the wether flock will be the first to be reduced, followed by the older ewes. Such sheep need to be expendable so that in poor years the farmer can afford to sell them cheaply in order to take the pressure off the pasture and remaining classes of stock. However, these same animals need to be capable of generating substantial income during favourable conditions if the farmer is to profit from a long-term forecast. On farms where flock size is increased by purchasing wethers, the cost of purchase is largely a function of their income-earning capacity and market trends. Where young stock are bred on the farm as replacements for the adult flock, the cost of keeping them includes the opportunity cost of not selling them as replacements. Hence the trading of stock with the capacity to generate substantial income during favourable conditions is not without cost and is likely to at least partly offset the benefit of responding to forecast changes in climatic conditions.

Lags and carryovers

Part of the potential benefit of the forecasts was not realized because of difficulties that wool producers have in responding in a timely and cost-effective manner. Periods of favourable climatic conditions were sometimes out of phase with the seasonal pattern of feed requirements of the flock making it difficult to fully utilize the additional feed grown. Also the sheep reproductive cycle and the annual cycle of management activities imposed practical constraints on the opportunity to respond to changing conditions. For example, additional wool grown in response to a change in management can usually be recovered only once a year (at shearing). This may require the sheep to be kept on the farm beyond a period of favourable weather conditions. Similarly, time is required in order to finish stock for sale. It can be difficult to dispose of stock that are not in good condition without incurring a penalty in price. Supplement can be used to improve their condition, but previous studies (White and Bowman 1987; Bowman 1989; Bowman *et al.* 1989*b*) have shown that it can be difficult to recover the costs of feeding to improve the weight of adult sheep in an extensive wool-producing enterprize.

In Victoria there are important carryover effects from one growing season to the next. For example, consider a situation where a good growing season is followed by a poor year with a very late start to the growing season. Stock numbers could be increased in order to take advantage of the favourable conditions in the first year. However, this would reduce the carryover of pasture to the second year and reduce the fat reserves of the sheep, leaving them much less able to withstand the late start to the next growing season. It may therefore be desirable to forego the opportunity to increase stock numbers in the first year in order to reduce the pressure on the pasture and stock in the second year.

Adequacy of long-range climate forecasts

The emphasis in forecasts produced to date is on the likelihood of above- or below-average rainfall occurring within the forecast period. Rainfall can have a major effect on pasture production in Victoria, particularly in the way it influences the time of germination and senescence of the pasture and hence the length of the growing season. The rate of pasture growth also tends to be more sensitive to below-average rainfall at the start and end of the growing season.

Research at Hamilton suggests, however, that for much of the *growing season* in southern Australia, pasture growth is most limited by temperature (Fitzpatrick and Nix 1970; Bowman *et al.* 1982). A year with cold winter temperatures and perhaps some waterlogging in winter and early spring can be as detrimental to pasture cover and animal welfare as a year where there is below-average rainfall combined with a late start to the growing season.

Other factors can also influence pasture growth at particular times during the year (Table 9). Both the magnitude and the timing of a climatic event are important; for example, the amount and timing of autumn rain in the way it influences the start of the growing season. References to good, average and poor seasons are inadequate though convenient generalizations that fail to acknowledge the complex interplay between climatic, pasture and animal factors which governs the quantity and quality of pasture available at different times in any one year and the impact that this has on the production and welfare of the animals grazing the pasture. At present the Bureau of Meteorology is producing a *qualitative* forecast of only one of the factors, albeit a very important one, influencing pasture production.

Table 9. A hypothetical example of how the key factors influencing pasture production at Hamilton can change in importance during the year

Month	Weather-related factors causing a major reduction in pasture growth		
Jan.	Insufficient soil moisture	High temperatures	
Feb.	Insufficient soil moisture	High temperatures	
Mar.	Insufficient soil moisture		
Apr.	Soil moisture marginal	Temperature marginal	
May	Low temperatures	Waterlogging	
June	Low daytime temperature	Frosts	
July	Low temperatures	Few sunny days	Waterlogging
Augt	Waterlogging	Low temperatures	Few sunny days
Sep.	Temperature marginal		
Oct.			
Nov.	Soil moisture marginal	High evaporative demand	
Dec.	Insufficient soil moisture	High temperatures	

Conclusion

This study has highlighted a number of prerequisites for long-range climate forecasting to be of value to farmers. Firstly, a very high level of accuracy of forecasting is required to ensure that most of the financial benefits gained through correct forecasts are not subsequently lost in years when the forecasts are in error. Secondly, buying and selling strategies for livestock need to be determined well in advance of adverse seasons if they are to be effective. Finally, seasonal forecasts in southern Australia need to provide quantitative information on the effect which forthcoming climatic conditions will have on pasture production, if these are to be used to accurately predict carrying capacity over the autumn and winter.

The study has also emphasized the need for a holistic approach to analysing agricultural systems in evaluating technological and managerial inputs (White 1993; Williams *et al.* 1993). Since a major benefit of climate forecasting is that it provides the opportunity for land to be destocked prior to drought, it is essential that the value of reduced damage to soils and vegetation through destocking prior to drought also be included in the final analysis. This protection of the soils and vegetation is in itself a prerequisite to attaining more sustainable agricultural systems.

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