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FODDER CONSERVATION IN THE SOUTHERN TABLELANDS WOOL INDUSTRY (1)*

ALAN G. LLOYD
Economics Research Officer

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* The second part of this article will be published in a subsequent issue of this *Review*.

Thanks are due to the graziers and extension officers who provided some of the information on which this article is based. In addition, the author has benefited from comments on the first draft, from the following people: K. A. Ferguson, F. H. Gruen, A. J. McIntyre, G. R. Moule, W. Musgrave, R. A. Pearse M. J. Phillips, R. W. Shelley, J. B. Truscott and D. B. Williams.

This article is part of an intensive study of the agriculture of the Southern Tablelands, being conducted jointly by CSIRO and the New South Wales Department of Agriculture. For details of this project—THE SOUTHERN TABLELANDS REGIONAL RESEARCH AND EXTENSION STUDY, readers are referred to *Report No.* 1, *Outline of the Project* (July, 1957), and *Report No.* 2, *Progress during* 1957 (July, 1958), copies of which are available from the Agricultural Research Liaison Section, CSIRO, Melbourne.

1. SUMMARY

In New South Wales and in some other States the conservation of pastures is rapidly ousting the conservation of crops. Pasture provided only 1.6 per cent of New South Wales' hay production in the 1946-50 period compared with 41 per cent in 1956-57. This trend is hardly surprising when it is realised that surplus growth of spring pasture provides a virtually costless material ready for harvesting, whereas hay or silage produced from crops involves not only harvesting costs, but a significant cost for conservable material. Wherever the rate of growth of sown pastures displays great variations within and between seasons which necessitate stocking at rates very low relative to average production, the periodic pasture surpluses which cannot be eaten by the stock available can be regarded as a virtually costless material for fodder conservation purposes.

Conserved fodder may be used either to increase or to stabilise total production, or to achieve various combinations of these aims. In many situations higher income and greater stability will be competitive goals between which the farmer must choose in formulating his fodder conservation policy.

The "minimum risk" policy involves using conserved fodder solely as an emergency reserve, feeding for survival in droughts, with no increase in stock numbers. Usually, however, the grazier with large drought reserves will follow a less conservative policy by modifying his feeding policy or his stocking policy: he may deplete his drought reserve to some extent by seasonal feeding to increase production per sheep and/or he may increase his stocking rate.

At the other extreme the grazier concerned solely with income might use all of his conserved fodder to permit increased stocking by means of seasonal feeding during periods of scarce grazing, so that his vulnerability to drought would actually be increased. A less extreme policy would be to set aside some hay as a reserve—at least sufficient to offset the drought needs of the additional sheep. Alternatively he may reduce risk by a smaller increase in stocking, permitting a higher level of feeding.

The profitability of some of these policies is discussed, using baled pasture hay as the form of conservation, and considering in turn conserved fodder used:

(i) for higher stocking,
(ii) for better feeding, and
(iii) for drought reserves.

The two major determinants of the unit cost of producing baled pasture hay are the yield of hay per acre and the scale of operations. Using cost figures provided by Yass Valley graziers and selected graziers in other parts of the State, and assuming three levels of production (50, 100 and 200 tons per annum) and a yield of 1.5 tons per acre, production costs are estimated at £4 to £6 10s. 0d. per ton "in the shed" or £5 to £8 per ton "fed out, after wastage". The importance of spreading overhead costs is clear, but is not reflected in the management of Yass Valley farmers, very few of whom use their hay-making machinery to reasonable capacity.

Of the three alternative uses of conserved fodder listed above, reasonable estimates of profitability with current knowledge are only possible for one—*seasonal feeding to permit increased stocking.* Throughout a large part of southern Australia the extreme variability of pasture production, both inter-seasonal and intra-seasonal, results in a very low degree of pasture utilisation. It has been estimated that in the Southern Tablelands of New South Wales less than 20 per cent of the total production of many improved pastures is being converted to meat and wool. Within seasons, most of the spring-summer feed is wasted, since stock numbers must be limited to those which can be carried through the winter. Similarly, between seasons, the stocking rate which will permit the bare survival of a flock in a drought year (pasture production in New South Wales, say 40 million tons) permits the utilisation of only a fraction of the good season's production (say 200 million tons). Fodder conservation of pasture hay for regular seasonal feeding can increase pasture utilisation in two ways: (i) *directly,* by the amount conserved less losses of nutrients in the hay-making process, (ii) *indirectly,* by increased pasture consumption in flush periods, made possible by a higher stocking rate.

A budget is given showing the profitability of conserving baled pasture hay for higher stocking of merino sheep on a fully pasture-improved property of 1,000 acres on the Southern Tablelands. The four major determinants of profitability are:

(i) The average period of seasonal feeding necessary and,

(ii) the level of technical efficiency of hay-making (which two factors together determine the number of additional sheep which can theoretically be run per ton of hay conserved), and

(iii) the wool price, and

(iv) the scale of operations and other factors affecting hay costs (which two factors together largely determine the net return per additional sheep).

At average yields, each acre cut for hay can theoretically increase carrying capacity by six to thirteen sheep, depending on (i) and (ii) above. The assumptions about each of the above four determinants are varied over three levels—"average", "optimistic", and "pessimistic", and profitability is thus estimated for eighty-one situations. Assuming approximate linearity the results from any combination of the four assumptions within or near the range assumed can be calculated by interpolation and extrapolation.

Within this range of assumptions, and with risk held approximately constant by compensatory drought reserves, the return on capital varies between 1 and 31 per cent per annum and net profits per ton of hay range from—£2 12s. 0d. up to £16. The wool price is the most important determinant of profitability. Over the immediate past—say, the 1952 to 1958 period when the price of Tableland merino wool averaged approximately 7s. 0d. per lb. net, of marketing costs—returns on capital of 20 to 30 per cent per annum could be obtained with only average efficiency. At the present low level of wool prices (4s. 6d. per lb. net for Tableland merino wool) attractive returns on capital (say 15-18 per cent) can only be attained in a reasonably favourable situation (seasonal feeding necessary, on average, no more than four months in every year) with above-average efficiency in hay-making. However, average conditions and average efficiency can give reasonable returns (around 11 per cent) even at current prices.

Using the parametric budgeting approach, a revenue formula is derived showing the effect of continuously varying the assumptions made about the important determinants of profitability. This can be stated as:

$$N = \frac{E}{5{\cdot}5\ P}\ (10.6\ W - 185) - H - 2(144)$$

where N is the net revenue per ton (in pence)

W is the wool price net of marketing costs (in pence)

E is the technical efficiency of hay-making (in food units per ton)

P is the average period of feeding (in weeks per annum) and

H is the cost per ton of hay (in pence).

An extension officer or farmer requiring an estimate of profitability for a given situation can substitute the figures appropriate for that situation in the above formula.

The practice of seasonal feeding of conserved fodder to raise the nutritional level of the flock is much more difficult to evaluate. The writer has not been able to find any field experiments in Australia which show that seasonal hand-feeding of adult merino sheep in normal seasons gives profitable returns in the form of higher wool cuts per sheep. Unfortunately, no firm conclusions can be drawn from this, because of inadequacies in the experimental data. There are two *a priori* reasons for suggesting that the wool returns from better feeding might be lower than from higher stocking—the higher utilisation of flush pasture growth in the latter case, and the fact that diminishing (wool) returns to feed apparently operate in the case of merino sheep, at least in the short run. Against this must be set the additional capital and running costs involved in higher stocking, and the higher risk.

In the case of fodder conservation for drought reserves, it seems that the grazier's decision as to the size of his reserve will remain more a psychological one reflecting his attitude to risk rather than a reasoned calculation of costs and returns. To calculate profitability in this case would require, for each degree of drought, a reasonable estimate of its probability of occurence, of its physical effects on pastures and stock, and of the long-term future price-cost situation. The period between droughts is of considerable importance, since it costs in the vicinity of 12s. 0d. per ton per annum to maintain a reserve of pasture hay, in addition to the cost of wastage in storage, and because the returns from drought feeding must be discounted over the period of waiting. To illustrate the range of financial results, three cases of fodder conservation for drought feeding are described, in which high profits, low profits and losses occur.

For most graziers the level of production required to maintain drought reserves will not permit a pick-up baler to be used to reasonable capacity, so that the profitability or otherwise of seasonal feeding has an important bearing on drought reserves. A grazier who is primarily interested in reducing risk rather than increasing income might follow the policy of the "costless drought reserve" using seasonal feeding and increased stocking as a means of offsetting the cost of his reserve. A costless or very low cost drought reserve of considerable size can be achieved by means of a moderate increase in stocking.

The conservation of pasture hay is only one of the approaches to the problems posed by the great variability of pasture production. The profitability of the programme budgeted would need to be compared with programmes based on grain, silage and fodder crops. For drought feeding, pasture silage is almost certainly a cheaper source of food units than pasture hay. On many Tableland properties the most profitable attack may be a combination of grain production from a grazed cereal crop together with the conservation of pasture hay and silage. Experimental investigation of the problems raised in this proposition, as well as other areas of ignorance discussed, would be extremely valuable.

2. INTRODUCTION

Over the past decade, one of the major components, and perhaps the most profitable, in agricultural investment, has been increased pasture *production,* through the use of improved varieties with fertilisers and trace elements. Given conditions favouring farm investment one of the next major developments in Australia's grazing industries, following increased pasture production, may be increased pasture *utilisation* through fodder conservation.

Until fairly recently fodder conservation in Australia was based almost completely on crops—mainly cereals and lucerne. The material to be conserved had first to be produced at a cost which varied widely around an average which is probably of the order of £3 to £4 per ton.[1] In the Southern Tablelands of New South Wales, and in many other areas of Australia, improved pastures can provide a nutritionally valuable conservable material which is virtually costless. Wherever the rate of growth of

[1] The estimate of £3 to £4 per ton is little better than an informed guess, though sufficiently accurate to illustrate the point made—that the cost of conservable material can be a significant one. The only detailed study of hay-making costs in Australia that the writer has been able to find was one by D. H. Penny and F. G. Jarrett, "Costs of Fodder Conservation on Murray Swamp Dairy Farms", *South Australian Journal of Agriculture,* February-March, 1957. Their study showed an average cost of £9.5 per ton for oaten hay, compared with only £5.2 per ton for meadow hay.

In some seasons winter grazing of cereal crops partially offsets the growing cost, but heavy grazing depresses hay yields and thereby increases the unit cost of both growing and harvesting the conservable material. Most crops which are grazed to any extent are harvested for grain rather than hay.

sown pastures displays great intra-seasonal and inter-seasonal variations which necessitate stocking at rates very low relative to average pasture production, the periodic pasture surpluses which cannot be eaten by the stock available can be regarded as virtually costless for fodder conservation purposes. Since this, in effect, probably means a reduction of one-quarter to one-half in the final cost of the conserved material in the shed, fodder conservation becomes a much more profitable operation.

Improved techniques developed in recent years are another factor which is encouraging the expansion of fodder conservation. The development of labour-saving machinery has been of particular importance because of the very short harvesting period for conserved fodder, especially hay. The advent of the one-man pick-up baler, the bale elevator and the tractor buck-rake has already had a considerable impact. In the Southern Tablelands statistical division, which includes 2,825 sheep properties, the number of pick-up balers increased to 307 in 1958, of a total of 513 hay balers. The one-man pick-up baler was not freely available in New South Wales until the late nineteen-forties, and no statistics are available prior to 1956, when there were 240 of these machines on Southern Tableland properties.

These two developments—the provision of a virtually costless conservable material following pasture improvement, and improved techniques for harvesting it—are in the process of altering the basis of fodder conservation in Australia. In the five years ended 1949-50, only 1.6 per cent of the hay harvested in New South Wales was pasture hay—11,000 out of 669,000 tons. This percentage rose rapidly to 33 per cent in 1955-56—278,000 out of 846,000 tons and 41 per cent in 1956-57—220,000 out of 538,000 tons, before falling to 17 per cent in the adverse 1957-58 season. The figures for other States show a similar trend, though the development occurred earlier in Victoria and Tasmania, where pasture has been the most important source of hay since 1948-49.

In anticipation of its important role in the future of the Region's agriculture, the Planning Committee of the Southern Tablelands Regional Research and Extension Study selected fodder conservation as one of the first aspects for detailed study. Some information on fodder conservation was obtained in a detailed survey of 137 farms in the Yass Valley in 1957. In addition, a mailed survey on fodder conservation has been conducted. Questionnaires have been sent to a small group of selected Yass Valley graziers and, through Department of Agriculture extension officers, to prominent fodder-conservers in other parts of the State. Using this information, an article on fodder conservation practices in the Yass Valley, and on the costs of fodder conservation, is being prepared for publication in a subsequent issue of this *Review*.

The present article will be confined to a discussion of the alternative uses of conserved fodder and the profitability of various fodder conservation policies, with a detailed examination of one particular conservation policy—seasonal feeding of pasture hay to merino sheep in order to increase the stocking rate. Attention will be concentrated mainly on baled pasture hay; it is hoped to discuss the other forms of fodder conservation, especially silage, in more detail in later articles.

3. ALTERNATIVE USES OF CONSERVED FODDER

The term "fodder conservation" covers a wide range of methods and objectives. Although a good deal of research has been devoted to technical aspects of harvesting, storing and feeding conserved fodder in its various forms, little attention has been devoted to the alternative policies open to the farmer in the use of this feed.

The Risk-Income Gradation

The grazier who commences a fodder conservation programme is immediately faced with the problem of whether he should store his fodder and build up a reserve, or use it for regular seasonal feeding. If he decides on a reserve he must decide how large it should be, under what circumstances should he draw on it, and whether or not the reserve would justify higher stocking. If he decides on regular seasonal feeding he must determine whether he should run extra stock, or concentrate on increasing the output of his existing flock by raising their nutritional level, or both. If, as is common, he decides on a mixture of these objectives, he must answer all of these questions, each of which represents a complex choice between income and risk.

A theoretical framework within which to discuss the profitability of alternative fodder conservation policies can be provided by "risk-income possibility curves". For a given climatic situation, wool price, etc., the effects on average farm income and on risk of a particular fodder conservation policy can be represented as points in Figures 1 (a) and 1 (b), p. 12. The measure of risk used for present purposes—a rather narrow one—is the percentage probability of a drought sufficiently severe to cause bankruptcy. The risk of losing the farm is the crucial one, rather than risk as measured by the average variability or standard deviation of annual income.

The initial risk-income situation without fodder conservation is represented by the origin O. The hypothetical curves show the alternative combinations of risk reduction and income increase attainable from a range of stocking policies and feeding policies applied to a given production of conserved fodder. Generally, the grazier must choose between higher income and greater stability. For a given quantity of fodder, these two goals may be either competitive, or complementary, or they may be complementary over a certain range before becoming competitive. However, if the quantity of fodder is increased a competitive stage must eventually be reached.

Theoretically, the grazier's optimum can be defined in terms of points of contact of his indifference curves with the curves shown, but the chance of giving much empirical content to this approach seems remote. However, this approach has been used because a classification is necessary of alternative fodder conservation policies, in terms of their relative contributions to income and to the reduction of risks, before any systematic discussion of the profitability of fodder conservation can be undertaken.

Although there are other factors, feeding policy and stocking policy are the two major considerations in determining the use to which a given quantity of conserved fodder is to be put. Figure 1 (a) shows the effect of varying the stocking policy with a given feeding policy, the latter being

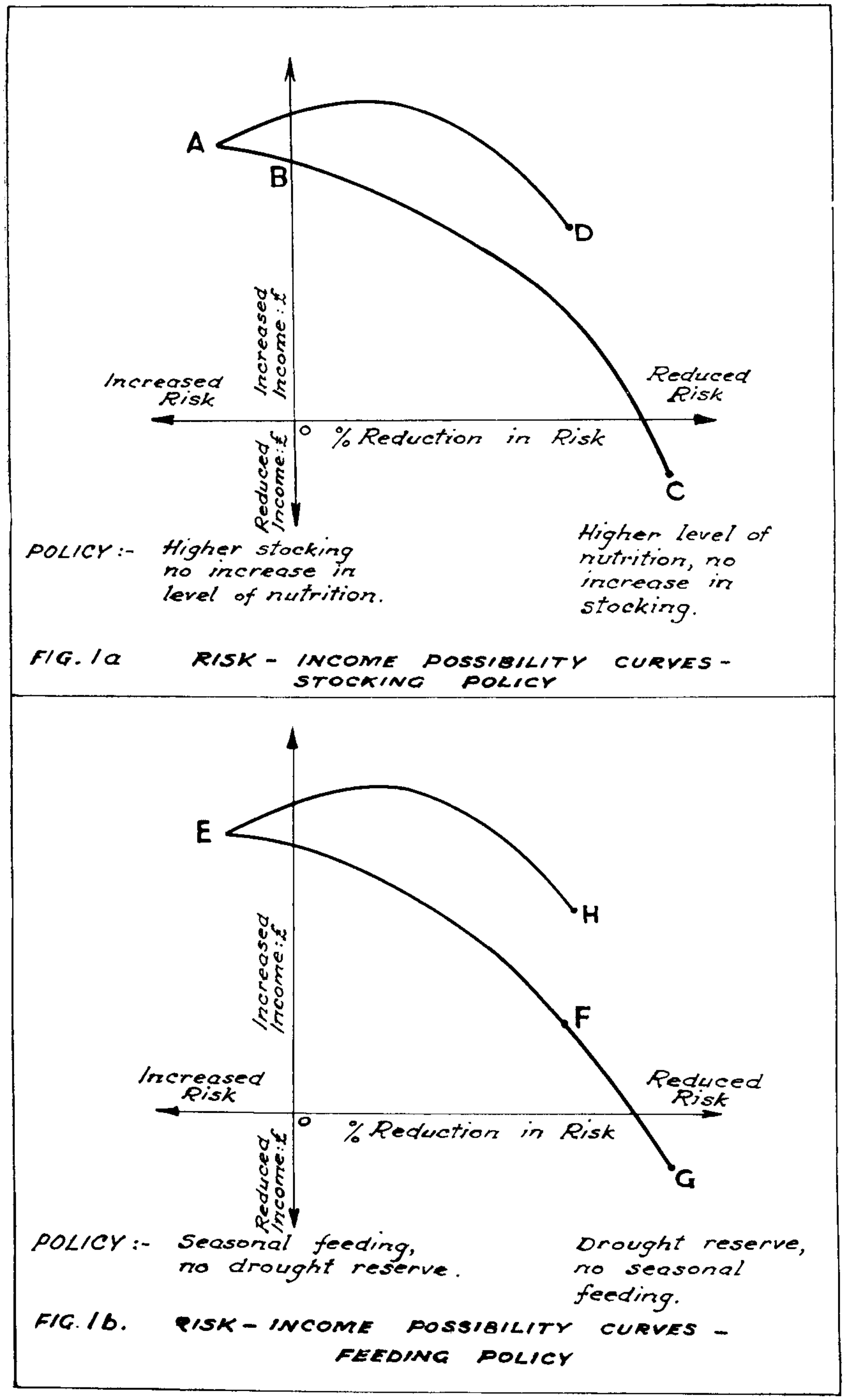
A
B
D
Increased Income: £
Increased Risk
Reduced Risk
0
% Reduction in Risk
Reduced Income: £
C
POLICY :- Higher stocking no increase in level of nutrition.
Higher level of nutrition, no increase in stocking.
FIG. 1a RISK - INCOME POSSIBILITY CURVES - STOCKING POLICY
E
H
Increased Income: £
F
Increased Risk
Reduced Risk
0
% Reduction in Risk
Reduced Income: £
G
POLICY :- Seasonal feeding, no drought reserve.
Drought reserve, no seasonal feeding.
FIG. 1b. RISK - INCOME POSSIBILITY CURVES - FEEDING POLICY

Fig. 1

defined in terms of the percentage of fodder production held as a drought reserve rather than fed seasonally. The curve ABC implies increasing net income and increasing risk with higher stocking. The results of experiments under field conditions suggest that conserved fodder used to carry more sheep will usually give higher monetary returns than if used to feed the same number of stock at a higher level. In many cases the wool response from better feeding may not even cover the cost of the feed (point C). However, it is possible that in some situations (discussed later) better feeding up to a certain level may be more profitable than higher stocking, especially where the capital cost of additional sheep is high, as on dry sheep properties. In any case, better feeding obviously involves less seasonal risk than higher stocking. Thus there may be a complementary phase, as shown by the curve AD, in which better feeding may increase both income and security.

Figure 1 (b) shows the effect of varying the feeding policy for a given stocking rate. The curve EFG depicts the situation in which the security attained by using the whole of the conserved fodder to build up a drought reserve is purchased at the expense of some sacrifice in income. In some low-risk situations the long-term average return from a drought reserve might be significantly lower than the returns from seasonal feeding with higher stocking, and in extreme situations drought reserves might involve losses. In other cases the reserving of part of the conserved fodder for drought contingencies may greatly increase income as well as security. This is especially likely to be the case in areas where sheep replacement costs are normally very high following drought periods and where droughts are frequent and of limited and relatively predictable duration.[2] This situation might be depicted by EH, which shows a complementary phase where an increase in the proportion of fodder held as a drought reserve increases both income and security.

Whether the point E in Figure 1 (b) is to the left or right of the vertical axis depends mainly upon the given stocking policy.

For purposes of illustration we take the case of a grazier running 2,000 mixed sheep on improved pastures who embarks on a fodder conservation programme involving the production of 100 tons of pasture hay per annum —an above-average quantity.

"Minimum Risk" Conservation

At one extreme of the risk income gradation, fodder can be held in reserve to serve as a form of drought insurance. In the "pure" case of "minimum risk" conservation, fodder is used solely as an emergency reserve to save stock in major droughts and is not drawn on to maintain production in bad seasons; furthermore, the existence of the reserve does not induce

[2] Some of the semi-arid pastoral areas of Queensland described by Everist and Moule would appear to fall within this climatic category. These are areas of high drought risk, and there is a very marked range in the percentage probability of effective rainfall between months, so that at certain seasons of the year there is a high probability of rain falling. A large proportion of droughts end in this period of relatively reliable rainfall. In the event of the drought not breaking at this time, the low probability of rain within the period following presents a fairly clear-cut situation for the grazier deciding whether or not he should sell his stock. See S. L. Everist and G. R. Moule, "Studies in the Environment of Queensland—2. The Climatic Factor in Drought", *Queensland Journal of Agricultural Science,* Vol. 9, No. 3 (September, 1952).

the farmer to make any increase at all in his stocking rate. Such a conservative policy aims solely at eliminating the more extreme seasonal variations in income and reducing the chances of bankruptcy due to heavy capital losses. It affects gross income only in the occasional period of major drought.

If the policy aims at reducing seasonal risk to a very low level, regardless of cost—*i.e.*, at building up very large reserves and storing them for very long periods, to counter the legendary "old man" drought—a long-term monetary loss might result. This loss would be of the nature of an insurance premium cost. In terms of Figure 1 (b), this extreme policy might be located at point G. A grazier with 2,000 sheep aiming to provide a reserve sufficient for eighteen months' feeding at an average of four food units per week would need to store over 800 tons of hay—eight years' production. "Complete" protection at this level would cost him as much as the gross value of two wool clips. (Hay fed out after a long period of storage—say, eight to ten years—could cost £10 to 15 per ton after allowing for wastage.)

"Maximum Income" Conservation

At the other extreme in the risk-income gradation is the case of the grazier whose fodder conservation programme is offset by a higher stocking rate, so that there is no net reduction in his overall risk position. In fact unless a reserve is carried sufficient to offset the drought requirements of the additional sheep, the degree of sasonal risk will actually be increased by this fodder conservation policy, in which case it might be represented by point A in Figure 1 (*a*). This usage could be termed "maximum income conservation"—a policy concerned solely with income.

There are two variants of the maximum income policy. One, which could be termed "intensive", consists in feeding out, in all seasons when it is necessary for maintenance, a quantity of fodder sufficient to offset the additional sheep carried. A grazier feeding out 100 tons per annum for an average of five months per annum—his period of seasonal feed shortage—could theoretically carry an additional 510 to 737 sheep. (The assumptions made in this calculation are given later.)

The other policy, which could be termed "extensive", is to stock at a higher rate, not as a result of conserved fodder actually fed, but as a result of the mere existence of a long-term drought reserve, which is considered by the farmer as offsetting the danger of the riskier stocking policy. If stocking is increased sufficiently, this policy too may actually increase seasonal risk.

This "extensive" policy is reflected in the answers given by a number of Yass Valley graziers to questions aimed at obtaining information on the effects of fodder conservation on their properties. A considerable number of these graziers suggested that they had increased their stocking rate as a result of fodder conservation, despite the fact that they did not make a practice of regular seasonal feeding. A typical comment was "I could not *risk* carrying the number of stock I have, if I did not have a fodder reserve". Generally, they also claimed increased safety as a result of their fodder conservation—*i.e.*, they had taken out some, but not all, of the benefits of fodder conservation in the form of higher stocking. Such farmers may have raised their stocking rate from near the "poor season level" (*i.e.*, the number of stock which could survive on their pastures in a "poor" season) to near the "average season level".

Hay which has been stored for such a long period that it has lost all or most of its food value is a fairly common (and much deplored) sight in many country areas. The role played by these long-term fodder reserves which are never or rarely fed may be more important than is generally realised. A grazier who, from consideration of risk, stocks at the "poor season level", is achieving a very low utilisation of feed perhaps four years in every five. The mere existence of reserves, quite apart from their ingestion, permits greater production.

It seems probable that a considerable number of graziers follow this policy to some degree, *i.e.*, the setting up of a drought reserve is followed by the adoption of less conservative stocking which nullifies, to some extent, the stabilising effect of the reserve. The ratio of fodder reserves to stock numbers is frequently used as an indicator of the degree of vulnerability to seasonal risk of a property or an area. However, if a rise in this ratio is likely to be associated with a riskier stocking policy, it may be a misleading criterion.

Intermediate Policies

Between the extremes (probably rarely practised) of reducing seasonal risk to an absolute minimum on the one hand, and concentrating attention entirely on increased production on the other, are intermediate policies which reflect the degree of risk aversion of the grazier.

At one extreme, a farmer following the minimum risk policy could, for income reasons, adopt less conservative policies by modifying either his stocking policy or his feeding policy, or both. If he were prepared to deplete his drought reserve he could feed more often: instead of feeding for survival only, in major droughts, he could feed to maintain production per animal in poor seasons, or even to increase production per animal by regular feeding in all average and below-average seasons. Alternatively, he could restrict his feeding to survival only, thus maintaining his reserve at a high level, but increase his stocking rate.

At the other extreme, the grazier who has taken out all the benefits of fodder conservation in the form of increased stocking might prefer a smaller increase in stocking in return for reduced risk. Similarly, he may prefer to reduce the scale of his seasonal feeding in order to set up a drought reserve.

Two other policies which are considered in more detail later are:—

(i) The policy of the "costless" drought reserve, stocking being increased only by sufficient to offset the costs of conservation, the bulk of annual hay production accumulating as a long-term drought reserve. The only benefits are those occurring in drought years and these are *net* profits. This policy could be represented by a point somewhere near F in Figure 1 (*b*), though the virtually indeterminate profits from drought reserves may in some cases be much higher than is indicated by point F.

(ii) The policy of "holding risk constant" by reserving only sufficient hay to offset the added risk of the increased stocking, the bulk of production being fed seasonally to additional stock. (Point B in Figure 1 (*a*).)

Also within the category of intermediate policies, which have the effect of both increasing income and reducing risk, are the various types of "special purpose" feeding, as distinct from feeding to increase the wool cut per sheep. For example, ewes and rams are often hand-fed prior to mating and ewes are hand-fed in late pregnancy, with the aim of increasing the lambing percentage; weaners are sometimes hand-fed to promote development and reduce losses. In a drought period, reserves ear-marked for these production purposes would, in the event, become maintenance rations.

4. PRODUCTION COSTS FOR BALED PASTURE HAY

As a preliminary to discussion of the profitability of various fodder conservation policies, an estimate is necessary of the cost of producing pasture hay with a pick-up baler—the most commonly used method of producing pasture hay on Yass Valley survey farms. Estimates are based largely on figures provided by selected Yass Valley graziers and prominent fodder conservers in other parts of the State, obtained through a mail survey currently being conducted. A detailed account of the results of this survey will be published in a subsequent issue of this *Review*.

The two main determinants of unit costs appear to be the scale of operations and the yield of hay per acre. Three levels of production—50 tons, 100 tons and 200 tons per annum—are considered, and the yield per acre is assumed to be 1.5 tons. Although this yield is higher than the recent average for the Southern Tablelands (1.29 tons per acre in the 1948-57 period), survey figures suggest that it is a reasonable assumption for well-improved properties, with which we shall be concerned in this article. Furthermore, a ten-year average yield is not an appropriate figure to use for an area where there is a marked upward trend in pasture production.

The capital costs, running costs and total costs for baled pasture hay are set out in Tables I, II and III, respectively. The assumptions on which these figures are based are given in Appendix I. It appears that total costs are probably within the range of £4 to £6 10s. 0d. per ton "in the shed" or £5 to £8 per ton "fed out, after wastage".

TABLE I

Capital Costs for Baled Pasture Hay

Item	Level of Annual Production		
	50 Tons	100 Tons	200 Ton
	£	£	£
Machinery—			
6-ft. Mower—£175			
8-ft. S.D. Rake—£200..			
P.T.O. Pick-up-Baler—£1,150 (Rated Capacity, 6-7 tons per hour)	1,525	1,525	1,525
Storage Shed(s)—£4 per ton capacity ..	200	400	800
Total	1,725	1,925	2,325

TABLE II

Harvesting Costs of Baled Pasture Hay—Man-Hours and Machine-Hours

(Assumed Yield 1.5 Tons per Acre)

Operation*	Man-Hours per Ton	Machine-Hours per Ton	
		Tractor-Hours	Truck-Hours
Mowing	0·50	0·42	..
Raking	0·40	0·33	..
Baling	0·41	0·30	..
Picking-up, Carting, Stacking†	1·36	..	0·30
Total	2·67	1·05	0·30

* Equipment as in Table I.

† A three-man team with hand-loading and stacking.

TABLE III

Annual Costs per Ton of Baled Pasture Hay

(Assumed Yield 1.5 Tons per Acre)

Cost Item	50 Tons	100 Tons	200 Tons
	s. d.	s. d.	s. d.
1. Machinery Overhead (£1,525)—Depreciation at 8, 10, 12 per cent. and Interest at 5½ per cent.	65 7	38 11	22 6
2. Running Costs in Harvesting—			
(i) 1·05 Tractor-Hours at 11s. 0d. per hour			
(ii) 0·30 Truck-Hours at 10s. 0d. per hour.			
(iii) Repairs and Maintenance on Hay-making Machinery at 5s. 6d. per ton.			
(iv) 2·67 Man-Hours at 7s. 6d. per man-hour.			
(v) Twine at 10s. 0d. per ton.			
Total	50 0	50 0	50 0
3. Storage	6 3	6 3	6 3
4. Fire Insurance	2 9	2 9	2 9
Cost—" In the Shed "	124 7	97 11	81 6
5. Feeding Out	10 0	10 0	10 0
Cost—" Fed Out, Excluding Wastage "	134 7	107 11	91 6
6. Wastage at 15 per cent.	22 0	17 3	14 5
Cost—" Fed Out, After Wastage "	156 7	125 2	105 11
Cost per Food Unit Fed Out (at 730 food units per ton)	2·57d.	2·06d.	1·74d.

The importance of spreading overhead costs is clear, but is not reflected in the management of Yass Valley graziers, few of whom use their equipment to reasonable capacity (to be discussed in a later article). Non-economic motivations are doubtlessly important in the purchase of farm machinery, but one suspects that many farmers have given little thought to the cost of excess capacity.

Contract rates for baling hay average about £4 10s. 0d. per ton "in the shed" in the Southern Tablelands—£5 per ton after allowing for storage and insurance. Comparing this figure with the costs shown in Table III it can be seen that graziers requiring less than 100 tons per annum could obtain their hay cheaper by contract. Other alternatives for small-scale hay producers are the sharing of equipment with neighbours and the adoption of methods of production involving lower overhead costs, such as loose hay or hay baled with a stationary baler.

5. THE PROFITABILITY OF ALTERNATIVE USES

Conserved fodder may be used:

(i) as a means of carrying more sheep without raising their nutritional level ;

(ii) as a means of increasing production per sheep by regular seasonal feeding, or

(iii) as a drought insurance.

Assessing the profitability of fodder conservation raises special difficulties. Each of the above three policies affects both farm income and risk, *i.e.*, the "returns" from each policy are usually a mixture of increased income and reduced risk. Furthermore, to judge by Yass Valley survey results, the fodder conservation programme adopted on any farm is generally a mixture of the above three policies. Usually, a grazier who has raised his stocking rate through fodder conservation will simultaneously improve the nutrition of his flock (or at least part of his flock at strategic periods of the year) and set up or increase his drought reserve.

In the case of (ii) and (iii) above—feeding for increased production per sheep and drought feeding—there is insufficient information available at present to permit any accurate budgeting of profitability, and the discussion is limited to generalisations about some of the factors which will affect the profitability of these uses of conserved fodder. In the case of (i)—feeding to increase the stocking rate—the problem is somewhat less complex and more experimental data are available, so that an attempt can be made to estimate profitability.

Fodder Conservation for Higher Stocking

Throughout a large area of southern Australia fodder conservation can and probably will unlock a very large production potential in the grazing industries. The size of this potential is indicated in the estimate that less than 20 per cent of the total production of many improved pastures in the Southern Tablelands is being converted to meat and wool.[3] This very low utilisation results from the extreme variability of pasture growth, both within and between seasons, in association with stocking rates which cannot be adjusted to short-term fluctuations in the feed supply.

Variability of Pasture Production

The pattern of pasture production within seasons in the Southern Tablelands of New South Wales is depicted in Figure 2, p. 20. Published pasture growth curves show a similar marked seasonality throughout a large part of southern Australia.[4] This seasonality is particularly marked in the case of improved pastures. Six to eight-fold increases in pasture production frequently result from pasture improvement, judging on experimental evidence, but wool production rarely increases by more than threefold.

To fully utilise spring production from a subterranean clover-based pasture would often require stocking rates of 10 to 20 sheep per acre, since subterranean clover produces about three-quarters of its annual production in the spring months. Yet in the winter months, when low temperatures inhibit pasture growth, carrying capacity is generally limited to one to two sheep per acre—less in poor seasons. In the majority of years, grazing properties in the area are greatly understocked in the spring-early summer when most of the available feed remains uneaten, and greatly over-stocked in the winter. Even though there is a carry-over of physiological reserves built up by the sheep in the spring-early summer, the compromise stocking policy adopted involves great waste.

The spring flush that is not eaten is very largely wasted. It becomes dry, low quality, summer feed—"standing hay"—which is often in surplus supply for part or all of the summer. Its nutritive value falls so low that the limiting factor is what the sheep can (and will) eat and digest, rather than the quantity available. In many seasons, on improved properties, more sheep could graze on this paddock roughage without affecting the already low nutritive intake of the initial flock. Eventually that portion which is not eaten rots, powders, or is trampled, and blows away or is otherwise lost.

The inter-seasonal variability of pasture growth is also striking. Willoughby has hazarded the guess that annual pasture production in New South Wales varies from 40 to 200 million tons between drought years and good seasons.[5]

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[3] "Doubling the Productivity of Improved Pastures", *Rural Research in CSIRO*, No. 15 (March, 1956), p. 22.

[4] For example, see R. C. Rossitter, "Grazing of a Veldt Grass-Clover Pasture", *Australian Journal of Agricultural Research,* Vol. 3, No. 2 (1952), p. 152—pasture growth at Perth, Western Australia.

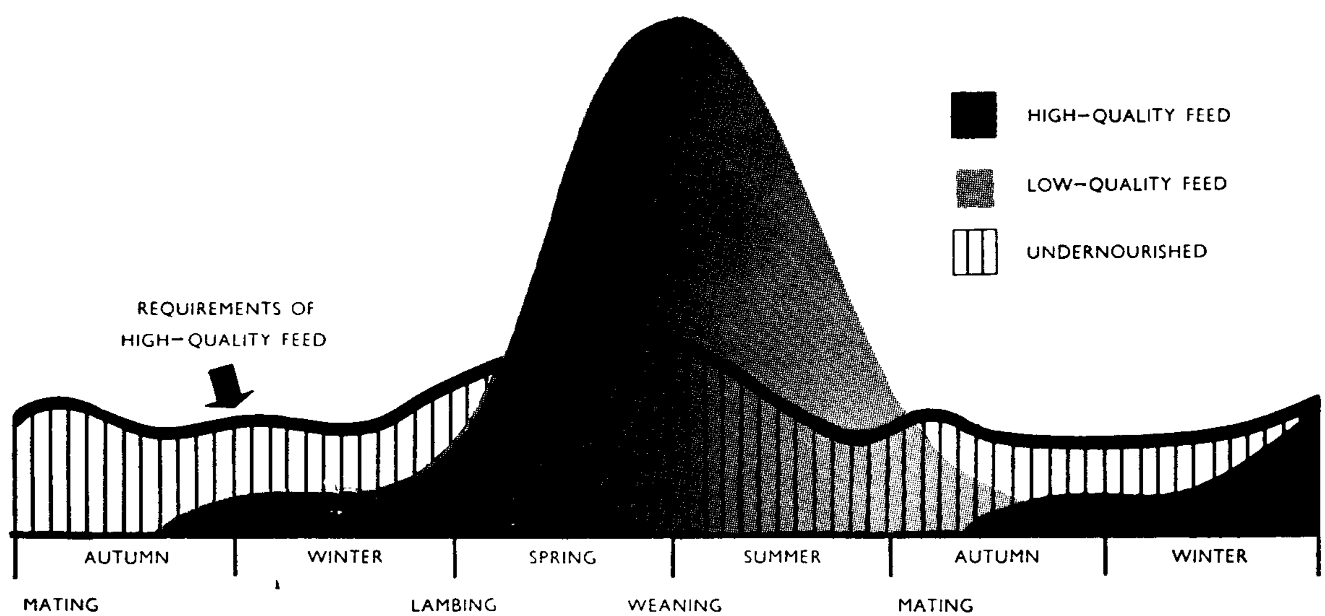
Moore, Barrie and Kipps, *Bulletin* 201, CSIRO, Figure 2 (1946)—pasture growth at Canberra, A.C.T.

E. J. Hilder, "Seasonal Pasture Production", *Proceedings of Australian Society of Animal Production,* Vol. 1 (1956), p. 38—pasture growth at Armidale, N.S.W.

A. C. T. Hewitt, *Feeding Farm Animals in Australia* (Sydney: Angus and Robertson, 1953), p. 76-8—pasture growth at Werribee, Caldermeade, Warragai and Korumburra in Victoria.

[5] "Stop Wasting Pastures", *The Journal of the Australian Institute of Agricultural Science,* Vol. 24, No. 1 (March, 1958), p. 65.

Fig. 2—The Pattern of Pasture Growth



The curves show the average annual pattern of growth of improved pasture in southern Australia in relation to the feed requirements of breeding ewes throughout the year. More feed is required by the ewe during spring because of the demands of late pregnancy and of lactation

Source: *Rural Research in C.S.I.R.O.* No. 15 (March, 1956), p. 23

The order of variability in the Southern Tablelands is probably not much lower. The stocking rate which will permit the bare survival of a flock in a drought season will obviously permit only a fraction of the good season's production to be utilised.

Climatic Factors

The climatological factors governing pasture production in the Yass River Valley have been studied by Slatyer.[6] For the five stations studied, average annual rainfall was 22.9 inches to 26.3 inches. *Variability in annual and seasonal rainfall is moderate.* In three-quarters of years, the annual rainfall at all stations examined exceeded 18 inches, and in nine years out of ten rainfall exceeded 16 inches. Slatyer divides the season into three main growth periods:

(i) *Pre-winter.*—Only limited growth occurs in this period in the majority of years. In only one year in four will growth commence in mid-March or earlier, because of inadequate soil water; the growth period ends by late April (the mean date of the first severe frost) to mid-May (by which time regular frosts are occurring). In three years out of four soil water is adequate before mid-May, so that some autumn growth occurs. However, this growth is less reliable than the spring flush upon which lambing is based.

(ii) *Post-winter.*—This, the main growth period, commences in late September, given soil moisture. In one year in ten, soil moisture has become inadequate by mid-October (very poor spring growth), and in one year in four by the end of October (poor spring growth). The median date for soil water depletion is November 20. Continued growth until early December can only be expected in a quarter of years.

(iii) *Summer.*—Growth during the remainder of the year is dependent on summer rains of adequate amount to cause significant soil storage. In nine years in ten, rainfall adequate to sustain four weeks' growth does occur in the November-April period. In the December-March period rainfall is adequate to support four weeks' growth one year in two, although rains adequate to initiate growth can be expected at least once per year. Thus, very little summer growth is fairly normal. However, a considerable (often surplus) quantity of dried-off low-quality spring growth is usually available during summer.

Raising Pasture Utilisation

The cutting of surplus spring growth for pasture hay to be fed to stock later in the year during the regular seasonal "drought" is one approach to the problem of closing "the feed gap". Since the stocking rate is largely governed by the length and severity of the feed gap and its

[6] R. O. Slayter, "Report No. 4—Climate of the Yass River Valley" (Regional Research and Extension Study, Southern Tablelands, N.S.W., 1959).

variability between seasons, such a policy makes possible higher stocking. Fodder conservation of pasture hay associated with increased stocking can increase pasture utilisation in two ways:

(i) *directly*, by the amount conserved less losses of nutrients in the hay-making process;

(ii) *indirectly*, by the increased pasture consumption in flush periods made possible by the higher stocking rate.

Is this method of attaining higher pasture utilisation profitable? Pasture hay is about twice as expensive a feed as grazed pasture. A good sown pasture provides feed at a cost of approximately 6d. per sheep-week, made up of interest on land and improvements plus rates, fertiliser and maintenance of fences and water supplies, whereas pasture hay produced efficiently at £5 per ton fed out costs approximately 1s. 0d. per sheep-week for a reasonable level of nutrition (say, 5.5 food units per sheep-week). However, the scope for profit lies in the fact that where virtually costless grazing of additional sheep on otherwise wasted pasture is possible for more than six months in the year on average, so that additional sheep require hand-feeding for less than six months per annum, the cost of feed per sheep-week on an annual basis is actually reduced by this policy.

Strangely enough this simple hypothesis, which has such obvious practical importance, has received very little attention from agricultural research workers.[7]

In the absence of direct experimental data, a partial budget will be constructed to show the effect on farm income of a fodder conservation—increased stocking programme through a range of assumptions. At the most this procedure will give some idea of the order of the results to be expected: at the least it is hoped to stimulate the interest of agricultural experimenters in a neglected field of research.

The Determinants of Profitability

The situation to be budgeted is that of a grazier on the Southern Tablelands of New South Wales with 1,000 acres fully pasture-improved, carrying 2,000 merinos and breeding his own replacements. Having brought his pasture production to a high level he now turns his attention to improving pasture utilisation, through hay-making, to permit further increases in his stocking rate.

Many graziers could increase their farm income by raising the stocking rate even without supplementary feeding. It is assumed that the stocking rate prior to fodder conservation is given, the grazier being stocked at what he considers to be his optimum rate in terms of risk and income.

[7] Willoughby's valuable work at Canberra on feeding silage to sheep lies in this direction. Willoughby is measuring the results of three treatments—nil conservation, one-third of each "farm" cut for silage, two-thirds cut for silage, the silage being fed back on the "farm" from which it was cut, in association with very high stocking rates. However, the experiment is not designed for direct farm management application; it is exploratory, seeking the long-term effects of a fodder conservation—increased stocking policy carried to the extreme, and the stocking rate is not treated as an experimental variable within each treatment. *See* W. Willoughby "Conservation as an Aid to Increased Pasture Utilisation", *Proceedings of Australian Agrostology Conference*, 1958 (Melbourne: CSIRO, 1958), Vol. 1, Part II, p. 54.

The four major determinants of profitability are:

(i) the average period of feeding necessary and

(ii) the level of technical efficiency of hay-making, which two factors determine the number of additional sheep which can theoretically be run per ton of hay conserved; and

(iii) the wool price and

(iv) the scale of operations and other factors affecting hay costs, which two factors together largely determine the net return per additional sheep.

It is the former problem—estimating the theoretically permissible increase in the stocking rate—which provides the main difficulties. This problem is one of deciding how many additional sheep could be run with a given quantity of hay for seasonal feeding, *such that the nutritional intake of the original flock is not affected*. This restriction on the partial budget, *i.e.*, holding the level of nutrition constant, is somewhat artificial, but is necessary because of our ignorance of input-output relationships in sheep feeding on pasture.[8] If the ratio of additional sheep to hay fed were such that the initial flock was affected, the awkward question would arise—"By how much"? It is necessary to construct feed-livestock "balance sheets", equating the addition to feed supplies (in the form of hay) with the "needs" of the additional flock for all of those months when pasture is not in surplus supply. This has been done in Table IV.

TABLE IV

*Increased Stocking Permitted per 100 Tons of Pasture Hay for Seasonal Feeding**

Average Number of Months of Feeding per Annum	Level of Technical Efficiency		
	Very Low—580 S.E. Fed per Ton Conserved	Average—730 S.E. Fed per Ton Conserved	High—880 S.E. Fed per Ton Conserved
	No. of Sheep†	No. of Sheep†	No. of Sheep†
4 Months (18 weeks)	586	737	888
5 Months (22 weeks)	479	603	727
6 Months (26 weeks)	406	510	615

* Assuming a highly impro ed property of 1,000 acres and a level of feeding of 5·5 food units per week.

† " Mixed " Sheep—Allowance is made within the average weekly ration of 5·5 S.E. per sheep for the additional requirements of ewes in late pregnancy.

The length of the seasonal feed gap is assumed to be four, five and six months per annum and the food value per ton of pasture hay, after wastage, has been assumed to be 580, 730 and 880 foot units (lb. starch equivalent). With the additional sheep being fed hay at an average of 5.5 food units per week throughout the feed gap, the theoretical increase in carrying capacity is estimated for each of the nine situations. Assuming a

[8] Ideally, the stocking rate, level of feeding and wool production per head should be considered simultaneously in the form of a multi-variate production function.

yield of 1.5 tons per acre, this table suggests that each acre cut for hay can increase carrying capacity by six to thirteen sheep per acre, depending on the level of technical efficiency and the period of feeding.

For the present, it can be assumed that the additional sheep are taken off pasture and hand-fed in yards whenever they are competing with the initial flock for scarce grazing. This somewhat artificial assumption, to be relaxed later, postpones consideration of the possible effects at times of increased grazing pressure on the pasture and other complications.

The Period of Feeding—Pasture growth curves give us some idea of the length of the seasonal feed gap, and of inter-seasonal variations. However, accurate measurement of the seasonal availability of feed from different pasture species and soils, under varying intensities and systems of grazing and varying seasonal conditions, and in relation to sheep needs, is largely unexplored. Accordingly it has been necessary to rely on the opinions of graziers and agronomists for estimates of the length of the feed gap, as defined below.

Graziers were asked the following question: "We are interested in regular seasonal feeding, *i.e.* the practice of using hay to offset the seasonal variation in pasture growth. Generally speaking, graziers are understocked for part of the year and overstocked for part of the year. Assume you increase your stocking by 25 per cent *on well-established improved pasture* (*e.g.,* 500 extra mixed sheep on a property initially carrying 2,000 mixed sheep). Assume you grazed the extra sheep whenever surplus pasture (even poor quality dry summer feed) was available which would otherwise be wasted, and hand-fed them in yards the rest of the year. On the average, good years and bad, *how many* months in the year would the extra sheep need to be hand-fed?"

Their answers are recorded in Table V and Figure 3, and give an average close to the answers given by agronomists in these areas.

TABLE V

Duration of Period of Feed Shortage Following Higher Stocking
(Months per Annum)

Statistical Division	No. of Farms	Range	Average
	No.	Months	Months
Northern Tableland	5	4–6	5·2
Central Tableland	6	3–5·5	3·6
Central Western Slope	4	2–7	4·1
Southern Tableland	7	2–7	4·1
South Western Slope	13	2–6	3·7
Riverina	6	3·5–6	4·4
Total	41	2–7	4·1

The average period of expected feed shortage was 4.1 months. The distribution of answers around this average was normal—twenty-nine of the forty-one graziers gave answers within the range three to five months, with five below this range and seven above it. However, because estimates of

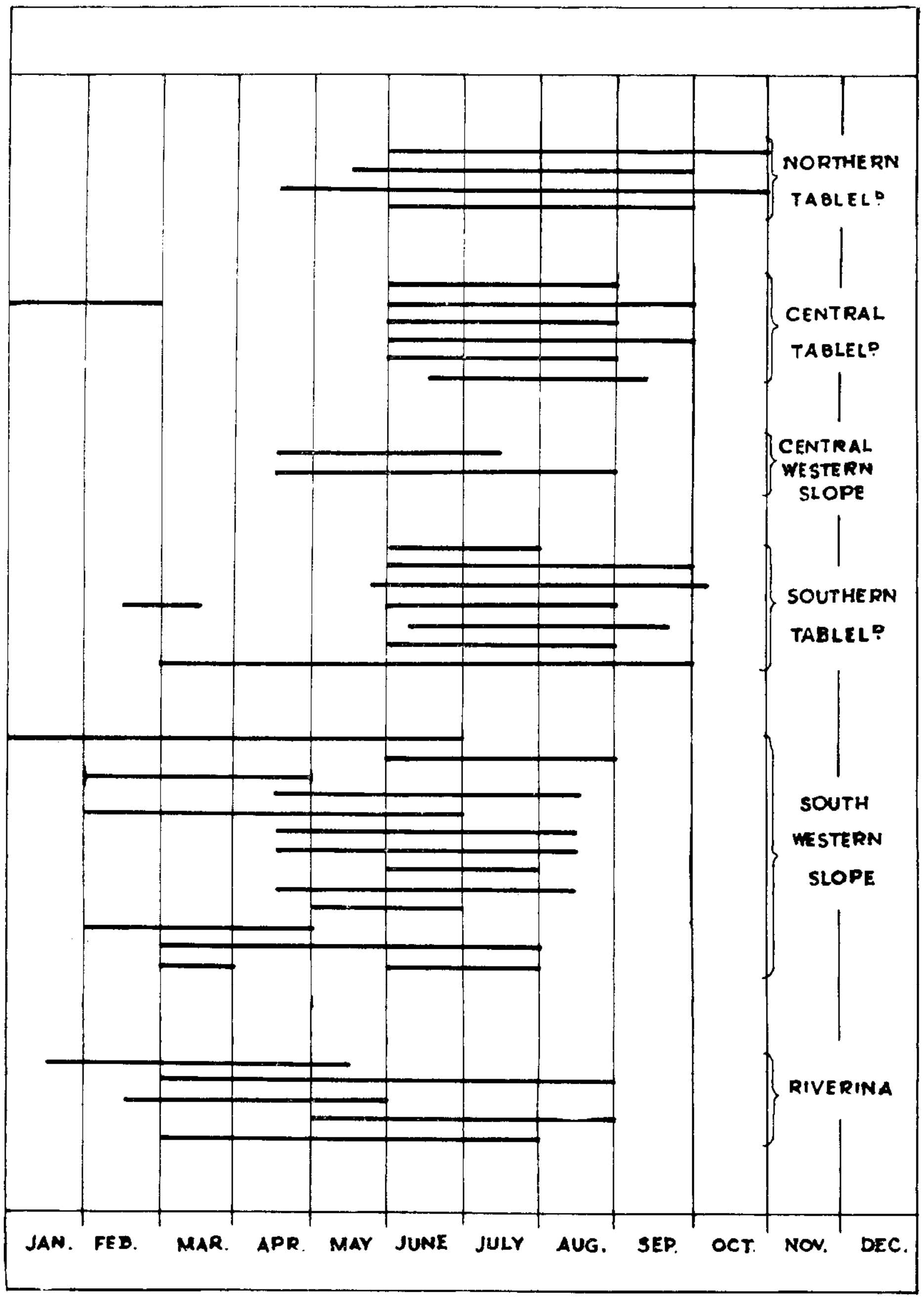


Fig. 3—The Period of Feed Shortage—37 Graziers

this nature, unverified by experiment, must be treated with caution, a range of four to six months has been assumed for the purpose of this budget, with the "average" assumption as five months. Only two of forty-one graziers gave estimates above this range. For further discussion of the period of feeding see Appendix II.

The Level of Feeding—The assumed level of feeding is an average of 5.5 food units per week—more for pregnant ewes and weaners and less for dry sheep. (The ewes' lactation period is not within the period of hand-feeding, since it is assumed that the ewes lamb on to the spring flush). This is equivalent to nearly 17 lb. of average quality grass-clover hay per week, before wastage.

Animal nutritionists consulted were unanimous that this is too generous a ration, but the budget has been designed to err on the side of pessimism. Certainly, the ration of 5.5 food units per week is well above maintenance requirements for dry merinos. In a recent experiment by Briggs, Franklin and McClymont, dry merino ewes maintained body weight on a weekly ration of four food units over a 223-day period. Weight losses occurred but deaths were negligible in a group fed three food units per week over the same period.[9]

For further discussion of the level of feeding see Appendix III.

The Level of Technical Efficiency—The criterion of technical efficiency used is the number of food units (lb. starch equivalent) eaten by sheep per ton of pasture hay conserved.

Losses of nutrients occur mainly in the harvesting process but significant losses also occur in storage and feeding out. The extent of these losses is discussed in Appendix IV. An estimate of the extremes of the quality range is given by Hewitt as 22 to 48 S.E.[10] Average quality pasture hay is generally quoted as being around 36 to 40 S.E.

For the case of average technical efficiency 730 food units per ton conserved has been assumed, after allowing for wastage in storage and feeding out. For a high level of efficiency—very good quality hay with minimum wastage—880 food units per ton is assumed, whilst poor quality hay inefficiently stored and fed out is assumed to provide only 580 food units per ton. Despite the arbitrary nature of these assumptions (no data on the quality distribution of farm hay are available) it seems reasonable to assume that the bulk of farm-produced hay should fall within this very broad range.

The Wool Price—The wool price assumed is 5s. 0d. per lb. net of marketing costs. Later this is varied, with "optimistic" and "pessimistic" assumptions of 6s. 0d. and 4s. 0d. per lb., respectively. Whilst the price of 5s. 0d. per lb. is very high, at the present time, in relation to the State average price for all wood (3s. 10d. per lb. net in February, 1959) it is probably only about 6d. per lb. above the current price for merino wool

[9] Briggs, Franklin and McClymont, "Maintenance Rations for Merino Sheep (IV)", *Australian Journal of Agricultural Research,* Vol. 8, No. 1 (January, 1957).

[10] A. C. T. Hewitt, *Feeding Farm Animals* (Sydney: Angus and Robertson, 1953), p. 134.

from the Tablelands. In the period 1954-55 to 1956-57 the average price received by Tablelands graziers included in the Bureau of Agricultural Economics Sheep Industry Survey was 18 per cent above the State average.[11]

Quite apart from fluctuations through time, the variation in the price received between properties is so wide that the use of a current State average price has little advantage. In applying this budget to any particular property, the results for the appropriate wool price (or the results from varying the assumptions on any of the three other major determinants of profitability) can be estimated with sufficient accuracy by interpolating within or extrapolating from Table VII, or from the revenue equation presented later.

Hay Costs and the Scale of Operations—Apart from yield per acre (assumed at 1.5 tons), the main factor determining the unit cost of pasture hay is the scale of operations. It is assumed that an average of 100 tons per annum is produced: whilst this figure is higher than the average output of Yass Valley graziers owning pick-up balers (61 tons per annum in the 1955-57 period) it is probably somewhere near the minimum production which would justify the purchase of such equipment. The effect on profitability of varying hay costs are shown later by also assuming the hay costs associated with 50 tons and 200 tons production per annum as shown in Table III.

Other Assumptions—Gross returns per sheep are estimated at 53s. 0d. derived from 9.5 lb. of wool at 5s. 0d. per lb. net and profit on the sheep trading account of 5s. 6d. per head. With wool at 4s. 0d. and 6s. 0d. per lb. net, gross returns per sheep are estimated at 42s. 6d. and 63s. 6d. per head respectively.

Net returns per sheep are obtained by deducting 11s. 0d. per head per annum for running costs—principally shearing, crutching, chemicals, rams, Pastures Protection Board rates, insurance and labour for sheep operations—and 4s. 5d. per head per annum for interest on the capital cost of the stock. It is assumed that the additional sheep are bought, though many graziers could breed them more cheaply, and that the flock is self-replacing except for rams. At an average of £3 10s. 0d. per sheep (ewes and wethers) and £30 for rams used at the rate of 2 per cent, the interest charge per 100 sheep at 5½ per cent is £22 3s. 3d. per annum, or 4s. 5d. per sheep.

No allowance is made in the budget for increased capital costs for fencing, water, buildings and yards, though these might be necessary on some properties if stocking were greatly increased. On properties stocked to capacity in relation to some or all of these items, capital costs up to £2 per head would be incurred in many cases, as a result of increased stocking.[12] Interest, depreciation and maintenance on the above items would reduce net annual returns per additional sheep by 2s. 6d. to 3s. 0d. per head.

Higher risks are entailed in carrying the additional sheep, both from the viewpoint of drought and the possibility of a succession of poor hay-making seasons. The estimation of a reserve sufficient to offset the additional risk must remain largely arbitrary. In this case a reserve is assumed equal to

[11] *Sheep Industry Survey—Summary of Physical and Financial Results*, 1952-53 *to* 1956-57, *High Rainfall Zone—N.S.W.*, Bureau of Agricultural Economics, November, 1958.

[12] F. H. Gruen and R. A. Pearse, "Aerial Pasture Improvement in New South Wales", this *Review*, Vol. 26, No. 2 (June, 1958), p. 115.

twice the average annual hay production. Thus the grazier producing 100 tons per annum and running 600 additional sheep commences each season with 300 tons of pasture hay after spring hay-cutting. This would generally be considered a very safe cover for 600 sheep. The reserve of 200 tons, after wastage, would provide full maintenance rations *for the extra sheep* for a period of approximately 60 weeks. The annual cost of the reserve would consist of storage (6s. 3d. per ton) insurance (2s. 9d. per ton), and interest on the running cost of harvesting the reserve (5½ per cent of 50s. 0d. = 2s. 9d. per ton) and on annual insurance premiums—a total of approximately 12s. 0d. per ton per annum.

Profitability—A Representative Case

Using the "average" assumptions made about the four major determinants of profitability discussed above, the financial results for a representative case are set out in Table VI.

Table VI

*Conserving Baled Pasture Hay for Increased Stocking—A Representative Case**

Annual Costs and Returns and Capital Invested

Details	Annual Production		
	50 Tons	100 Tons	200 Tons
Additional Sheep Carried	301	603	1,206
Additional Gross Income per annum at 53s. 0d. per sheep .. .. £	800	1,598	3,196
Additional Annual Costs (Including Interest at 5½ per cent)—			
Hay Costs (1 to 5, Table III) .. .. £	336	540	915
Sheep Costs at 15s. 5d. per head .. £	232	465	930
Hay Reserve at 12s. 0d. per ton .. £	60	120	240
Total Costs .. .. .. £	628	1,125	2,085
Additional Net Income .. .. .. £	172	473	1,111
Net Profit per ton produced (Above Interest at 5½ per cent)	£3 9s. 0d.	£4 15s. 0d.	£5 11s. 0d.
Capital Invested† .. .. £	3,604	5,683	9,841
Percentage Return on Capital (per cent)	10·3	13·8	16·8

* At 5s. 0d. per lb. for Tableland Merino wool, with five months seasonal feeding, average technical efficiency, and a hay yield of 1·5 tons per acre.

† Includes capital costs for machinery and storage, as in Table I; the capital cost of the drought reserve for the additional stock at 52s. 9d. per ton for harvesting and insurance and £4 per ton for storage capacity; and the capital cost of stock at £4·03 per 100—£3 10s. 0d. per sheep and £30 per ram at 2 per cent.

With wool at 5s. 0d. per lb. net, and with risk held approximately constant by compensatory drought reserves, the return on capital from fodder conservation for higher stocking is conservatively estimated at 10 to 17 per cent per annum according to the scale of operations, whilst the net profit per ton fed is estimated at £3 9s. 0d. to £5 11s. 0d.[13]

[13] For small and perhaps average-size farms, Table VI exaggerates to some extent the effect of economics of scale, since the 200 tons per annum programme would necessitate a longer period of feeding than the 50 tons per annum programme. The effect of a longer period of feeding is shown later.

For the case of the grazier running dry sheep, it would be necessary to amend the budget in Table VI in a number of ways. Although higher wool cuts might be expected and more sheep could be run, the heavy cost of replacing stock, say every five years, would result in slightly lower profitability (a return on capital around 11 to 12 per cent for the grazier producing 100 tons per annum).

A well-improved farm has been assumed. If the property were at an early stage of pasture development, lower wool cuts per sheep would need to be assumed, the period of feeding might be longer, and lower yields per acre would result in higher hay harvesting costs. For these reasons fodder conservation for higher stocking is significantly more profitable on highly improved farms than on properties which are in the early stages of pasture improvement. This fact, together with evidence indicating that pasture improvement generally yields higher returns than those shown in Table VI, suggests that the programme budgeted here would rate a lower priority than pasture improvement on all but the highly developed Tableland properties. Gruen and Pearse estimate the *discounted* return on capital from aerial pasture improvement at 13.7 to 19.1 per cent per annum, with wool at the price assumed in Table VI—5s. 0d. per lb. net.[14]

In actual fact the grazier who conserved 100 tons of hay per annum and could, in theory, thereby run an additional 600 sheep would be more likely to increase his flock by say 200 to 400. He would use the rest of the "carrying capacity" of the hay to obtain higher wool cuts and lambing percentages by regular supplementary feeding of his whole flock, and to reduce his drought losses by building up a reserve for the whole flock. The effect on profitability of this "mixture" of uses cannot be accurately estimated at present. However, the profitability of fodder conservation with higher stocking, as estimated, at least locates one point on the risk-income possibility curve. A grazier who, *with adequate knowledge,* "trades" a certain amount of income for greater stability is presumably at least as well off on his own scale of preferences.

VARYING THE ASSUMPTIONS

In farm management extension, one of the main weaknesses of the static budgeting approach has been that single assumptions (or a very limited number) are generally made about important variables. In this article, the assumptions made about each of the four determinants of profitability are varied over three levels—"average", "optimistic" and "pessimistic", and profitability is thus estimated for 81 situations (*see* Table VII, p. 30-31). The approximate results from assuming other levels can be obtained by interpolating within and extrapolating from Table VII, within the range in which approximate linearity can be reasonably assumed.

[14] Gruen and Pearse, *op. cit.* See also F. H. Gruen, "Financial Aspects of Pasture Improvement on Southern Wheat-Sheep Farms", this *Review*, Vol. 24 No. 4 (December, 1956).

TABLE VII

Profitability of Conserving Baled Pasture Hay for Increased Stocking—Varying the Assumptions

Average Number of Months of Feeding per Annum	Level of Technical Efficiency*	Cost per Ton (In the Shed)† and Annual Production: £6 4s. 7d.—50 Tons per annum		£4 17s. 11d.—100 Tons per annum		£4 1s. 6d.—200 Tons per annum	
		Profit per Ton‡	Per cent Return on Capital	Profit per Ton‡	Per cent Return on Capital	Profit per Ton‡	Per cent Return on Capital
		£ s. d.	Per cent	£ s. d.	Per cent	£ s. d.	Per cent
Wool at 4s. 0d. per lb. net							
6 Months per annum	Very Low	—*2 12 0*	1·4	—*1 2 0*	3·2	—*0 5 0*	4·8
	Average	—*1 0 0*	4·0	0 12 0	6·6	1 2 0	7·9
	Very High	0 8 0	6·1	1 15 0	8·5	2 11 0	10·6
5 Months per annum	Very Low	—*1 8 0*	3·4	—*0 10 0*	4·5	0 4 0	6·1
	Average	0 5 0	5·8	1 11 0	8·3	2 8 0	10·4
	Very High	1 18 0	8·0	3 5 0	10·7	4 1 0	13·0
4 Months per annum	Very Low	—*1 0 0*	4·1	1 7 0	7·9	2 3 0	10·0
	Average	2 1 0	8·2	3 8 0	10·9	4 4 0	13·2
	Very High	4 2 0	10·4	5 9 0	13·4	6 5 0	15·8
Wool at 5s. 0d. per lb. net.							
6 Months per annum	Very Low	—*0 10 0*	4·8	1 0 0	7·6	1 17 0	10·0
	Average	1 13 0	7·9	3 0 0	11·1	3 15 0	13·8
	Very High	3 13 0	10·5	4 19 0	14·1	5 16 0	17·1
5 Months per annum§	Very Low	1 2 0	7·1	2 0 0	9·4	2 15 0	12·9
	Average	3 9 0	10·3	4 15 0	13·8	5 11 0	16·8
	Very High	5 15 0	13·0	7 1 0	16·9	7 18 0	20·1
4 Months per annum	Very Low	2 2 0	8·4	4 8 0	13·4	5 5 0	16·3
	Average	5 19 0	13·2	7 5 0	17·2	8 2 0	20·3
	Very High	8 16 0	16·0	10 2 0	20·3	10 18 0	23·5

TABLE VII—*continued*

Profitability of Conserving Baled Pasture Hay for Increased Stocking—Varying the Assumptions—continued

Average Number of Months of Feeding per Annum	Level of Technical Efficiency*	Cost per Ton (In the Shed)† and Annual Production					
		£6 4s. 7d.—50 Tons per annum		£4 17s. 11d.—100 Tons per annum		£4 1s. 6d.—200 Tons per annum	
		Profit per Ton‡	Per cent Return on Capital	Profit per Ton‡	Per cent Return on Capital	Profit per Ton‡	Per cent Return on Capital
		Wool at 6s. 0d. per lb. net.					
6 Months per annum	Very Low	1 13 0	8·1	3 3 0	11·9	4 0 0	15·2
	Average	4 7 0	11·8	5 7 0	15·6	6 9 0	19·7
	Very High	6 19 0	15·0	8 4 0	19·8	9 0 0	23·6
5 Months per annum	Very Low	3 12 0	10·9	4 10 0	14·2	5 5 0	19·7
	Average	6 11 0	14·6	7 18 0	19·4	8 14 0	23·2
	Very High	9 11 0	17·9	10 18 0	23·1	11 14 0	27·1
4 Months per annum	Very Low	5 4 0	12·8	7 10 0	18·9	8 6 0	22·6
	Average	9 16 0	18·2	11 3 0	23·4	11 19 0	27·4
	Very High	13 9 0	21·6	14 15 0	27·1	15 11 0	31·2

* 580, 730 and 880 food units fed out per ton of hay produced.

† The three cost levels shown are those estimated as representative for graziers producing 50, 100 and 200 tons of hay per annum respectively, based on a yield of 1·5 tons per acre.

‡ Profit per ton after deducting interest on capital at 5½ per cent—*i.e.*, nil profit per ton is equivalent to a return on capital of 5½ per cent.

§ The representative case discussed in the text.

Note.—The cost of additional sheep is a non-recurring cost, since replacements are bred. Therefore the sheep price, which is slightly above current levels, has not been varied with the different wool prices. A grazier who commenced a fodder conservation—higher stocking programme when sheep prices were higher than the level assumed would need to adjust these figures accordingly.

This elaboration of budgeting serves the same purpose as a more formal approach developed by Candler, which he has termed parametric budgeting.[15] This method, which is analogous to the development of parametric programming from linear programming, uses a revenue equation which permits the *continuous* variation of selected parameters. A revenue equation for the budget discussed here is presented later.

Within the range of assumptions covered in Table VII the return on capital varies between one and 31 per cent, whilst net profit per ton conserved ranges from −£2 12s. (*i.e.*, a loss after allowing for interest on capital) up to £16. Not surprisingly, the wool price is the most important determinant of profitability. Low technical efficiency or a long period of feeding reduces costs as well as income, since the effect is to reduce the number of additional sheep which can be carried.

At current prices for Tableland merino wool (approximately 4s. 6d. per lb. net in February, 1959) fodder conservation for higher stocking only gives attractive returns on capital (say 15 to 18 per cent) where the average period of feeding does not exceed four months and where above-average efficiency is attained either through a large scale of operations or through technical skill in hay harvesting. However, even with five months feeding per annum, reasonable returns (around 11 per cent) can be obtained at current prices for Tableland wool, given average efficiency. On properties on which six months feeding per annum would be necessary, only a high level of efficiency and a large scale of operations would ensure reasonable returns.

The "break-even price" for Tablelands merino wool, making the average assumptions for technical efficiency and scale of operations, is as follows:

4 months feeding per annum—3s. 1½d. per lb.

5 months feeding per annum—3s. 6d. per lb.

6 months feeding per annum—3s. 9½d. per lb.

At these prices (which include allowance for proportionately lower profits on sheep trading) the return from the programme budgeted just covers interest of 5½ per cent on capital invested.

The average price received for merino wool from the Tablelands over the past six years has been in the vicinity of 7s. per lb. net. Applying this figure to Table VII, the type of programme budgeted apparently would have been extremely profitable over that period to a large number of graziers. Returns on capital of 20 to 30 per cent per annum could have been obtained with only average efficiency. The fact that a greater expansion of fodder conservation has not occurred in the Tablelands has a number of explanations:

(i) As mentioned earlier, only on well-improved properties would fodder conservation have been as profitable as is suggested above;

(ii) On relatively undeveloped properties pasture improvement was a more attractive investment opportunity and had prior claim to scarce funds;

[15] W. V. Candler, "A New Look at Budgeting from the Standpoint of Linear Programming", paper read at the Third Conference of the Australian Agricultural Economics Society, Melbourne, February, 1959.

(iii) In practice, a large proportion of the hay conserved is used for purposes other than increased stocking. It is possible, that pasture hay as it is actually used in a "mixture" of uses is less profitable (ignoring risk considerations) than the usage budgeted here. Certainly, gains in the form of increased stability are less obvious and tangible than gains from higher stocking, and to that extent may be less widely appreciated.

THE REVENUE EQUATION

A simple revenue equation can be assembled to calculate net return per ton of hay from a fodder conservation—higher stocking programme. The most important parameters to be varied are:

the wool price net of marketing costs (in pence) —W,

the cost per ton of hay (in pence) —H,

the level of technical efficiency (in food units per ton) —E,

the level of feeding (in food units per sheep per week) —F,

the average period of feeding (in weeks per annum) —P,

and the size of the hay reserve, measured as a ratio of the reserve to the quantity fed annually —R.

E, F and P together give X—the number of additional sheep to be carried per ton of hay at any given level of feeding ($X = \frac{E}{FP}$).

In Table VII, F and R are not varied: nor are the assumptions regarding wool cut per head and annual sheep costs per head. These may be varied in the formula below.

Profits on sheep trading, which will vary with the wool price, can be expressed on a per sheep basis in terms of pounds of wool—in this case 1.1 lb. per annum.

Net revenue per ton of hay in pence (N) can be calculated by multiplying sheep per ton (X) by (returns per sheep—costs per sheep) and subtracting the cost per ton of hay fed and the cost of the hay reserve. Making the assumptions used in Tables VI and VII—*i.e.*, costs per sheep at 185d. per annum, the annual cost of the hay reserve at 144d. per ton, the ratio of hay reserve to annual feeding as 2:1, the level of the feeding at 5.5 food units per sheep per week, and the wool cut per head as 9.5 lb.—then the formula becomes:

$$N = \frac{E}{5.5P}(10.6W - 185) - H - 2(144)$$

An extension officer or farmer requiring an estimate of profitability for a given situation can substitute the figures appropriate for that situation in the above formula.[16]

[16] The small discrepancies between the results obtained from this equation and those in Table VII occur because the latter figures are "rounded off", and "fractions of sheep" are ignored.

Pasture Management

Instead of fully hand-feeding the additional sheep in yards or in a "sacrifice" paddock (due for resowing or cropping), it should often be possible to graze them, taking the additional stress off the pasture by *supplementary* feeding of the whole flock. A reduction in pasture intake has frequently been noted, following experimental feeding of supplements.[17]

This raises two interesting questions:

(i) The effect on total pasture production of supplementary feeding.

(ii) The substitution relationship between hay and pasture.

At certain periods, and particularly in poor seasons, higher stocking might severely damage pastures, despite the fact that the requirements of the additional sheep are theoretically balanced by the supplementary feeding. In such circumstances yarding might be necessary. At other times, however, supplementary feeding may permit increased pasture production despite the higher stocking. For example, Sergeant has written,

> "With new growth after autumn rains it is common practice to extensively graze the holding, so that the short growth will give keep to livestock until sufficient volume builds up and allows the use of smaller areas. The alternative is to confine stock to small areas and supplement the pasture by feeding hay or silage. After several weeks, a change of paddocks will give a larger volume of grazing, and as a progressive policy, the supplement is cut down as pastures build up and are more capable of providing total requirements.
>
> "Winter pastures supplemented with hay will contribute more grazing than is possible without supplementation and, except in unfavourable seasons, it is possible to stretch the grazing in this way to bridge the winter gap where it would frequently be necessary to feed 100 per cent on stored fodder for some weeks if optimum thrift in livestock is to be achieved."[18]

On the second question, the difficulties involved in measuring and controlling pasture intake would make very complicated the experimental measurement of substitution relationships between hay and grazed pasture at various stages of growth. However, such research is urgently needed. In some situations fewer food units are required for a given response from a mixture of hay and grazed pasture than from either feed alone. Sergeant touched on this point in suggesting that "During periods of low pasture production the higher digestibility of the grazed pasture which results from supplementation has a strong bearing on the economics of fodder conservation programmes."[19]

No allowance can be made for the above possible benefits of fodder conservation in this budget, which could therefore understate profitability quite considerably. On the other hand, the maintenance intake of grazing wethers

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[17] See G. L. McClymont, "Response of Stock to Supplementary Feeding on Pastures", *Proceedings of the Australian Society of Animal Production,* Vol. 1 (1956), p. 63.

[18] A. F. Sergeant, "Fodder Conservation", *Proceedings of the Australian Society of Animal Production,* Vol. 1 (1956), p. 119-120.

[19] *Loc. cit.*

may be considerably higher than that of yard-fed sheep.[20] The net effect of these considerations as between feeding full maintenance rations to the additional sheep, and grazing them with supplementary feeding of the whole flock, is likely to be a complicated question.

Unlike the spring flush, autumn growth can be saved, which gives the farmer some choice as to when to feed. He may prefer supplementary feeding in autumn rather than in winter, enabling him to "autumn-save" a large proportion of his paddocks.

Fodder Conservation for Higher Levels of Nutrition

The writer has not been able to find any Australian experiments under field conditions which show that seasonal hand-feeding of adult merino sheep in normal seasons gives profitable returns *in the form of higher wool cuts per head*. Unfortunately, a firm conclusion cannot be drawn from this, since the experimental data are inadequate. McClymont has drawn attention to one of the main inadequacies:

> "Feeding of supplements of conserved roughage or concentrates is widely recommended as a means of preventing the effects of poor pasture on growth or milk production of stock. However, when evidence of the quantitative response to such supplementary feeding is sought as a basis for rational advice on the practice, it is found that the responses have been most erratic and far less than would have been expected on the basis of feeding standards."

McClymont goes on to state that the most obvious explanation is that the supplementary feeding has resulted in a lower pasture intake, and after calling for further study of this problem, concludes that "until data from such studies are available, advice on supplementary feeding for production must remain empirical and the results largely unpredictable." [21]

Raising the plane of nutrition for reasons other than increased wool growth—for example, feeding ewes and rams at mating and ewes in late pregnancy, and supplementing the diet of weaners and lambs—falls into a different category. Unfortunately, the experiments that have been done in Australia in this field have used supplements other than pasture hay (usually concentrate mixtures and grain). The protein content of the hay, which is very variable, would be an important factor governing responses.

Seasonal feeding of merino sheep on the Tablelands is usually aimed at stopping the severe loss of weight and associated reduction in wool growth which occurs in most winters. Whilst beneficial effects on body weights have been observed (see, for example, Hindmarsh, *et. al.*) these are unlikely to be of much commercial importance.[22] Until it is proved otherwise under

[20] For example, see L. J. Lambourne, "The Use of Animal Production Measurement Methods in Pasture Evaluation", *Proceedings of Australian Agrostology Conference,* 1958 (Melbourne: CSIRO, 1958), Vol. 1, Part II, p. 51-6.

[21] G. L. McClymont, *loc. cit.*

[22] "Whilst many of the supplementary rations were of some value in that the sheep did not lose weight to the same degree as those on natural pastures alone, they were costly beyond all proportion to the benefits obtained in any one year." W. L. Hindmarsh, J. C. Cotsell, H. A. Grantham and E. A. Elliott, *Studies in Sheep Nutrition in the New England District of New South Wales,* N.S.W. Department of Agriculture, Division of Animal Industry Leaflet, 1948, p. 4.

field conditions, woolgrowers might be well advised to accept winter weight losses, consoled by the fact that the fasting sheep grows wool at the expense of its other tissues. As McMeekan has suggested, "the most effective use of grassland frequently involves the temporary abuse of both pasture and animals." [23]

The two main advantages of using conserved hay for better feeding rather than higher stocking are the reduced risk from adverse seasons and the avoidance of the capital and running costs involved in carrying more sheep. These costs are lower on breeding properties (estimated at 15s. 0d. to 16s. 0d. per head per annum) than on properties running wethers, where stock replacement and running costs are around 25s. 0d. per head per annum. On the other hand, there are two *a priori* reasons for suggesting that returns from using conserved fodder for better feeding may be lower than returns from feeding for higher stocking:

(i) Conserving pasture hay for increased stocking permits a higher utilisation of flush pasture growth through the cheapest method of feeding—grazing.

(ii) Under some circumstances the law of diminishing returns apparently operates quite strongly in the case of feeding for wool, at least in the short term. Research workers have shown that each additional unit of feed, measured in terms of protein, above maintenance requirements produces considerably less wool.[24] A dry merino ewe (100 lb.) grazing good pasture might eat ¾ lb. (350 grams) of crude protein per day. If the sheep were of average capacity, it would convert 3.6 per cent of this protein to wool. At a maintenance intake of 150 grams per day, it would convert 5.2 per cent of the protein into wool. Wool production per acre of feed could theoretically be increased by over 40 per cent by restricting the pasture eaten per sheep, assuming pasture availability were not significantly affected by the higher stocking.

However, some important recent finding by Ferguson (unpublished) throw new light on the feed-wool relationship. Ferguson found evidence suggesting that "it is energy rather than protein intake which determines the wool growth response to increasing feed intake in diets ranging in crude protein content from 8.5 to 35 per cent of the dry matter." Furthermore, the diminishing returns to feed studied by Ferguson, Carter and Handy relate to the short-run: ". . . the efficiency of conversion at feed intakes above maintenance is associated with the diversion of absorbed nutrients into the synthesis of body tissues . . . and the increase in efficiency at intakes below maintenance is associated with the supply of energy for wool growth from catabolised body tissues." [25] After the eventual adjustment of the sheep to the new level of intake, the response may be near-linear over a considerable range.

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[23] C. P. McMeekan, "Interdependence of Grassland and Livestock in Agricultural Production", *Proceedings of Sixth International Grasslands Conference* (1952), p. 161.

[24] Ferguson, Carter and Handy, *op. cit.*

[25] K. A. Ferguson, "The Efficiency of Conversion of Feed into Wool", (unpublished).

The fact remains that whatever the shape of the response curve in various time-periods, the wool cut per acre under field conditions with constant fluctuation in intake will depend to an important extent on the degree of utilisation of pasture growth. In experiments on rates of stocking, such as those carried out by Cotsell at Shannon Vale, higher stocking rates have been associated with considerable increases in wool per acre.[26]

In situations where hand-feeding results in a lower degree of pasture utilisation—the problem raised by McClymont—an estimate of the value of hand-feeding must include allowance for the value, if any, of the grazing saved. Where this grazing is not later consumed, it will have no value. However, in some situations, such as where hand-feeding in autumn results in more grazing being available in winter, it may have a considerable value.

The budget shown in Table VI can be adjusted to allow a comparison between 100 tons of pasture hay used for raising nutritional levels compared with its use for higher stocking. In the case of better feeding the capital invested is reduced to £1,925 for machinery and storage, since the capital cost of additional stock and the hay reserve they require is avoided. Similarly, annual costs are reduced to £540. To return 13.8 per cent on capital, the annual gross income from the hay must reach £806. Some financial benefits are likely to accrue from better sheep health and from reduced drought losses, but these would be very difficult to estimate. Leaving these aside for the moment, an additional output of approximately 32 lb. of greasy wool per ton of hay would be required to yield a profit as high as that obtained through higher stocking.

An unselected group of merino ewes used by Ferguson at Prospect showed a *net* efficiency of conversion of 2.25 lb. of clean dry wool per 100 units of starch equivalent (net efficiency represents the efficiency of conversion when bodyweight change is zero). With pasture hay yielding 730 units of starch equivalent per ton after wastage, this is equivalent to a return of approximately 33 lb. of greasy wool per ton of hay (using a 50 per cent conversion from greasy to clean wool). However, under farm conditions, with supplementary-feeding of hay being partially offset by reduced grazing, the extra wool produced per ton of hay fed might fall well below the break-even point of 32 lb. mentioned above. For better feeding to be as profitable as higher stocking, the gap would need to be covered by the monetary benefits of the better sheep health and lower drought risk associated with better nutrition.

Even where it could be shown that better feeding was less profitable than higher stocking, risk considerations would induce some graziers to use their conserved fodder for the former policy. However, the possibility would need to be considered that the same reduction in risk might be achieved more profitably by using part of annual hay production to build up a drought reserve and the remainder to support higher stocking.

[26] J. C. Cotsell, "Sheep Management and Pasture Use", *Agricultural Gazette of New South Wales*, Vol. 69, Part 4 (April, 1958), p. 177.

Fodder Conservation for Drought Feeding

Most discussions of the profitability of drought feeding are grossly oversimplified. Frequently the type of conclusion which emerges is: "A ton of hay (or silage, etc.) costing say £6 to produce will keep four sheep for about a year. The wool grown pays for the hay and the sheep are saved for next to nothing."

If we had only one-year droughts to contend with, and these were announced well in advance, the above would be a fair enough statement. In actual fact, the problems involved in budgeting costs and returns from drought reserves appear to be insuperable.

Three Cases

Some of the complexities which bedevil the economics of drought feeding can be illustrated by considering the following three hypothetical cases of very high profit, very low or nil profit, and a loss. Assume a grazier sets up a drought reserve of 100 tons of hay of initial quality sufficient to provide maintenance rations (4 food units per sheep per week) for 692 sheep for six months (hay providing 730 food units per ton after wastage).

Case 1: If the drought commenced in the year following the setting up of the reserve, and broke just as the reserve was exhausted, the main cost of saving the sheep would be say £540 for the hay (at a cost of £5 7s. 11d. per ton fed out, as in Table III). The returns could be estimated on the basis of the number of sheep saved (after allowing for normal deaths) multiplied by the value added to the sheep, together with the value of wool grown by surviving sheep during the six months of hand-feeding.

There are a number of alternative methods of valuing the sheep saved. Sheep saved which would have died could be valued at their replacement cost after the drought, less the value of skins taken from dead sheep. Alternatively, the value added to the sheep by hand-feeding could be taken as the difference between their market price early in the drought—usually very low—and after the end of the drought—usually very high. By either method, £2 to £3 per head would be a reasonable estimate. If wool is valued at 4s. per lb. net of marketing costs, profits from the drought reserve as high as £12 to £20 per ton can be calculated.[27] If the hay were of high protein content, and were used to supplement very low quality paddock roughage which, without supplement would not enable sheep to survive, the number of sheep saved per ton of hay fed could be much higher, and even greater profits would be obtained from the hay reserve.

Case 2: To illustrate a result which is much less favourable, no major drought might ensue until ten years after the reserve was set up. In this case the cost of the hay would double, as a result of ten years of interest, storage and insurance at approximately 12s. per ton per annum.

[27] This simple calculation includes only the major costs and returns. For example there is no allowance for labour costs, except in feeding out. Nor is there any estimate of the delayed effect on pastures, in terms of later pasture recovery, of feeding versus not feeding.

If the drought ended less conveniently—not when the reserve was exhausted but six months later—the purchase of fodder would be necessary for any return to be obtained from the hay already fed.[28] Maintenance rations of wheat for the second six months at 17s. 6d. per bushel landed in bags, added to the cost of the hay used in the first six months, would give a total feed bill exceeding £2,100—four times that of Case 1.

The gross returns from the drought reserve would also be greatly reduced. Due to wastage in storage the 100 tons of hay which represented maintenance rations for 692 sheep for six months in Case 1 might only maintain say 500 to 600 sheep for that period ten years later. A return of £800 might be allowed for the value of the wool produced by say 550 hand-fed sheep over the 12 months. On these assumptions, unless the value added to the sheep by hand-feeding exceeds £2 10s. per head (*i.e.* replacement costs after the drought exceed initial value by £2 10s.) then virtually no profit has resulted from the drought reserve. Even if a value of £3 10s. per head is assumed (presumably the longer the drought, the higher the subsequent level of sheep prices) the final profit per ton of hay conserved will be quite small after it has been discounted for the ten years of waiting.

Given the extreme variability of our climate, one might guess that drought reserves are generally much more profitable than in Case 2. In any case, it is not unreasonable that an insurance measure should involve a cost in the nature of a premium. At the same time, graziers in areas of relatively low climatic risk certainly cannot be condemned out-of-hand for preferring stabilisation measures other than fodder reserves, especially of hay.[29] Financial reserves and physiological reserves on the sheep through "under-stocking" are alternative methods of offsetting seasonal risk.

Case 3: There is an even less favourable case to consider. A drought reserve differs from a commercial insurance transaction in that the reserve may actually *increase* the financial loss resulting from the event "insured" against. When the drought outlasts both the fodder reserve and the funds available to buy fodder, the grazier finds that "It would have been cheaper to let the stock die". To the losses of stock and income in the drought year(s) would be added the costs of the fodder reserve and the purchased fodder.

Within the extremes of case 1 and case 3 are a range of results of varying degrees of probability of occurrence. If it were possible to obtain a frequency distribution of the probabilities of droughts of various magnitudes, together with a monetary estimate of the losses which would result from each in the absence of a fodder reserve, some calculation might be made

[28] If the probability of receiving effective rain over the second six month period were very low, the grazier might decide to "cut his losses" by selling his sheep off-shears as soon as his hay reserve was exhausted. This approach, using rainfall probability as a criterion for decision-making, has been developed by Everist and Moule (*op cit.*). In this case the only return from drought feeding would be the net value, after shearing and marketing costs, etc., of six months' wool growth. With wool at 4s. per lb. net, this return would be approximately £400. Against this must be set the cost of the hay fed—say £1,000, plus the loss involved in selling the sheep late in the drought instead of early in the drought, which might easily exceed £1 per head.

[29] On a food unit basis, the annual cost of storage, insurance and interest is much lower in the case of silage than the figure of 12s. per ton per annum used above.

of the *average* profitability of drought reserves. Rather than using recommendations based on averages, it may be preferable in some cases to use game theory to suggest optimum "strategies" against nature.[30] However, it is not likely that sufficiently accurate data will be available.

A study of rainfall records would certainly indicate the probability of periods of "low" rainfall of varying durations (assuming no long-term changes in climate). However, the problem of relating this to pasture production and thence to animal production and stock losses is more than formidable.

Even assuming comprehensive long-term rainfall and agricultural statistics were available, enabling a fruitful study of the relationship between climate and production, this relationship is constantly changing as a result of new varieties and productive techniques and changes in the physical environment (such as declining fertility trends). If a climatic period identical with the 1895 drought were experienced today, it could certainly not be assumed that the effects on production would be identical. Even if these difficulties could be overcome, so that for each degree of drought we had estimates of the probability of its future occurrence and of its physical effects on pastures and stock, the problem would remain of translating these physical effects into monetary terms. This would require a long-term forecast of wool prices and of stock prices before and after the hypothetical drought.

Faced with such complexity, it seems that the grazier's decision as to the size of his drought reserve will remain more a psychological one than a reasoned economic calculation of costs and returns.

Drought Reserves with Seasonal Feeding

The profitability or otherwise of regular seasonal feeding has an important bearing on drought feeding. The costs of a drought reserve can be considerably reduced if regular seasonal feeding is also practised. There are two reasons for this.

First, seasonal feeding can provide a profitable means of turning over hay stocks in order to reduce wastage, which is frequently a heavy cost in long-term reserves. Second, a more frequent turning over of stocks through seasonal feeding and increased production will lower unit costs of production significantly by spreading overhead.

If a grazier running 2,000 sheep wishes to use his pick-up baler to anywhere near capacity he must produce hay for seasonal feeding as well as a drought reserve. Most Yass Valley graziers aim at a reserve of less than six months maintenance rations per sheep, and their aims are well in excess of their actual reserves. The majority of these graziers on properties carrying around 2,000 sheep would consider a reserve of more than 300 tons as excessive. Even if the incidence of droughts were such that this quantity was fed out every four years, the drought reserve would require the production of only 75 tons of hay per annum. Yet Hewitt estimates the capacity

[30] For an example of this approach applied to a similar problem (seasonal variability of crop yields) see E. R. Swanson, "Problems of Applying Experimental Results to Commercial Practice", *Journal of Farm Economics*, Vol. 39, No. 2 (May, 1957) p. 386-9. Theoretically a payoff matrix incorporating stocking rate and size of drought reserve could be assembled.

of the pick-up baler, working with two mowers and two rakes, at approximately 600 tons per season.[31] Only graziers on very large properties would hold as a long-term reserve the large quantity of hay which would result from a pick-up baler used reasonably near to capacity with no regular seasonal feeding. Whilst unit production costs would fall with larger reserves, each additional ton stored would have a lower "insurance" value, being a contingency against a more remote risk.

It is rather surprising to find that over one-third of the Yass Valley graziers who own pick-up balers do not practice seasonal feeding, and most of this group carried less than 3,000 dry sheep equivalents.

The grazier who does not wish to undertake regular seasonal feeding, but who wishes to produce hay for a drought reserve, can avoid over-capitalisation by using a hay press or stationary baler rather than a pick-up baler. Hewitt estimates the capacity of these presses at 150 tons per season.[32] However, the high labour requirements of this method make it unpopular. Other alternatives are contracting, the sharing or hiring of equipment, and the sale of hay. The latter method is rarely practised in the Yass Valley. Freight and handling costs for hay are usually very high in relation to market value, particularly when the sale is for the purpose of turning over old stocks of poor to medium quality.

A grazier who is primarily interested in reducing the risk of his operations rather than intensifying them might follow the policy of the "costless drought reserve", by using seasonal feeding as a profitable "by-product" offsetting the cost of his reserves.

The Costless Drought Reserve

This policy involves increasing the stocking rate only by sufficient to cover the costs of fodder conservation, using part of the fodder conserved for regular seasonal feeding to offset the requirements of the additional sheep, and the remainder to build up a costless reserve.

With merino wool at 4s. 0d. per lb., it can be shown that a grazier producing an average of 100 tons of pasture hay per annum, and aiming at a costless drought reserve of about 400 tons of pasture hay, could achieve this position in approximately eight years, with no drought intervening.

In year 1 he would need to increase stocking by approximately 250 sheep to recoup his hay costs.[33] About 40 tons of his hay production would be required to offset the needs of the additional sheep, leaving nearly 60 tons to form the nucleus of his reserve. In later years, as the reserve increased it would be necessary to cover the costs of insurance and storage at approximately 9s. 0d. per ton per annum. Thus further increases in stocking would be required. Finally, however, with the required reserve attained, and no further increase in stocking being required, most of annual hay production could be used for seasonal feeding or sold (stocks being turned over in the process). The proceeds would permit a reduction in stocking so that in the final analysis perhaps only 200 to 250 additional sheep would be required to completely offset fodder conservation costs.

[31] A. C. T. Hewitt *op. cit.*, p. 87.
[32] Hewitt, *loc. cit.*
[33] Wool at 4s. 0d. per lb. net with the "average" assumptions used earlier.

In this situation the return from fodder conservation in normal years would be nil, but the cost of the drought reserve of approximately 400 tons would also be nil. Thus, all of the returns from fodder conservation, under this policy, would be taken out in the form of lower risk, and reduced losses of income and capital in drought years. The 400 tons reserve would provide full maintenance rations (4 S.E. per sheep per week) for a flock of 2,000 sheep for approximately eight months, after allowing for the drought needs of the additional sheep required to finance the reserve.[34] It seems that a costless or very low-cost drought reserve should not be difficult to achieve by means of a moderate increase in stocking.

In the apportioning of their hay production between reserves and seasonal feeding for increased stocking, many graziers probably approach this position without consciously planning for it.

6. OTHER APPROACHES TO PASTURE VARIABILITY

The conservation of pasture hay is only one of the approaches to the problem of low pasture utilisation and the extreme variability of pasture growth. The financial results from this approach need to be compared, by budgeting or programming, with fodder conservation in the form of grain and silage, and with the sowing of fodder crops either for grazing or for dual purposes (grazing-hay or grazing-grain).

Silage

To judge on contract rates, pasture silage may be a cheaper source of food units than pasture hay, especially if the feeding-out problem can be overcome by successful self-feeding or specialised equipment. Certainly pit silage is a cheaper form of *long-term* storage. No insurance is required, wastage is much lower, and annual storage costs per 100 food units (interest and depreciation on the structure) are very low—about 3.5d. compared with 6.5d. for grain (in a silo) and 10d. for hay. Its principal disadvantage for seasonal feeding—high handling costs in feeding out, is a less important consideration in drought feeding. Although the machinery costs for silage are much lower than for baled hay, only large properties can support both operations. A few Southern Tableland graziers overcome this problem by holding their long-term drought reserves in the form of pit silage produced under contract, using hay for regular seasonal feeding.

Grain

Grain also entails lower costs of storage and wastage than pasture hay, as well as low handling costs in feeding out. For these reasons it is quite popular as a drought reserve. If the grain is purchased, however, the initial cost per food unit will frequently be twice that of pasture hay or silage.

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[34] Whilst such a policy would greatly reduce seasonal risk in short or medium-term droughts, the additional stocking would constitute greater risk in a very prolonged drought. Furthermore, Dr. Williams has pointed out to me that some of the additional risks involved in higher stocking cannot be offset by drought reserves—for example, the risk of an outbreak of serious disease in the flock.

Prices for feed oats in New South Wales can be taken as an example. In recent years, graziers could buy oats grown in their district at the following prices (annual averages, landed on the farm in bags): [35]

1954—8s. 6d. per bushel; 4.11d. per food unit.

1955—7s. 2d. per bushel; 3.47 d. per food unit.

1956—5s. 10d. per bushel; 2.82d. per food unit.

1957—9s. 1d. per bushel; 4.40d. per food unit.

1958—8s. 5d. per bushel; 4.07d. per food unit.

Adding 0.30d. to 0.40d. per food unit to the above figures to cover wastage, storage costs and feeding out costs, it can be seen that the total cost per food unit from purchased oats has been around 4d. in recent years. In the case of hay produced with average efficiency—say £5 per ton fed out, after wastage—the cost per food unit is only 2d.

The above annual average prices disguise wide fluctuations. A few graziers make a practice of buying oats in large quantities for long-term storage whenever prices fall to very low levels. In two periods within the past five years (November-December, 1955, and November-December, 1958) oats could have been purchased for just under 5s. 0d. per bushel landed on the farm. At this price, the final cost per food unit, fed out after wastage, would have been approximately 2¾d. Only if the oats price fell to 3s. 5d. per bushel landed would it be comparable with pasture hay at £5 per ton fed out. However, many graziers are prepared to pay a somewhat higher price for oats in order to avoid the "costs of trouble" in hay-making.

On some properties oats could be produced at a price lower than the figure of 3s. 5d. per bushel mentioned above, especially where they are grown as a dual-purpose fodder crop yielding winter grazing.

Fodder Crops

The popular practice of cutting or stripping cereal crops after winter grazing represents a two-pronged attack on the problem of the feed gap. Since fodder crops may give little or no grazing in unfavourable seasons, a combination of fodder cropping with fodder conservation is required if stocking is to be increased as a result of the cropping programme.

Where fertiliser costs are very low (such as on the Northern Tablelands) and where cropping for renovation of resowing is a necessary part of the pasture programme, the fodder crop may be grown very cheaply. Furthermore, this cost may be completely or partially offset by the value of the winter grazing obtained, so that the grain harvested may involve little or no net cost.[36]

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[35] These prices are based on unweighted averages of *State Marketing Bureau* quotations for prices at Alexandria. Alexandria prices are usually about 2s. 0d. per bushel higher than the return to growers paying average freights, and probably about 1s. 6d. per bushel higher than the landed price of oats on properties close to the grower.

[36] Since we are discussing well improved properties, where ample pasture is available for hay-making in most years, it is assumed that the fodder crop is stripped for grain.

It is a surprising fact that there seems to be no experimental data available enabling estimates of the sheep-weeks of grazing which might be expected from grazing oats (or wheat) later stripped for grain, together with associated yields. A number of farmers and agronomists on the Tablelands have given estimates ranging from 30 to 80 sheep-weeks per acre (mixed sheep) as long-term averages, good seasons and bad, after deducting an allowance for the pasture grazing which would have been available from the cropland. If the grazing is valued at 1s. 0d. per sheep-week (the cost of a weekly ration of 5.5 food units of pasture hay at £5 per ton) the resultant grazing return of 30s. 0d. to 80s. 0d. per acre would in many cases completely offset the variable costs of growing and harvesting the grain. (On small grazing properties the fixed costs, particularly the cost of harvesting machinery, would be very high in relation to the limited amount of crop needed for winter grazing, and contract harvesting might be advisable).

The low-cost or "costless" grain could be used to provide feed in drought periods and for regular seasonal feeding outside the grazing period of the crop. However, in valuing the oats for feeding purposes the opportunity cost (the income sacrificed by not selling the oats) must be taken into consideration. Whenever grain prices were at reasonable levels, supplementary feeding outside the grazing period of the crop could be financed more cheaply by using the proceeds of the sale of the grain to produce pasture hay or pasture silage, or both. This combination of grain production from grazed cereal crops with the conservation of pasture hay and silage may be a more profitable approach on many Tableland properties, particularly the large ones, than the programme based solely on pasture hay which was budgeted earlier. As an illustration, if an oats crop cost £4 per acre to sow and harvest, provided an average of 50 sheep-weeks of additional grazing per acre, and yielded an average of 12 bushels of grain sold which is at 5s. 0d. per bushel net, the net cost of the winter grazing would be £1 per acre or 5d. per sheep-week—considerably cheaper than feeding pasture hay.

7. CONCLUSION

Perhaps the most important conclusion emerging from this discussion is the magnitude of the investment opportunity open to graziers through the conservation of pasture, given reasonable wool prices.

In March, 1958, there were over 10,000,000 acres of improved pasture in New South Wales, excluding paspalum and including self-sown pastures. A large proportion of this pasture was used to carry the State's 65,000,000 sheep. The current practice is to cut less than 2 per cent of this area for pasture hay and silage. Even on the conservative assumptions of Table IV, the conservation of only 20 per cent of this pasture would theoretically increase the State's carrying capacity by 17,000,000 sheep (plus or minus 6,000,000).

Almost certainly, however, the increase in stock numbers would be more moderate, and a considerable part of this theoretical increase in carrying capacity would be used by graziers to reduce risk through drought reserves. This mitigation of production uncertainty in such an important sector of our economy could have far-reaching effects, both for farm management and for policy.

Considerable uncertainty stems from the vagaries of our knowledge, as well as our climate. The conclusion that more research is needed in the field discussed may be unoriginal, but it is also inescapable.[37] Until agricultural experimenters can remedy this, rational decision-making in management aspects of fodder conservation will be seriously restricted.

APPENDIX I

Production Costs—The Assumptions

Capital Costs

The capital costs assumed are set out in Table I. It is assumed that a tractor is already available on the property and is not fully utilised. If this were not the case a portion of the overhead cost of this item would be chargeable to the hay. Admittedly, additional hours worked in a hay-making programme would tend to shorten the tractor's working life, and in recognition of this higher repair costs might be allowed in the tractor costs of hay-making. If tractor overhead (interest and depreciation) were charged to hay-making in proportion to the tractor hours spent on hay-making, this might amount to 5s.—15s. per ton of hay for a farmer producing 100 tons per annum. It is assumed that a lorry is available for picking-up, carting and stacking. Alternatively a trailer could be used with the tractor.

Depreciation on the hay-making machinery (mower, rake and baler) is calculated at a flat 10 per cent per annum ($12\frac{1}{2}$ per cent per annum less allowance for resale value) for the case of 100 tons annual output. This figure may be rather high in relation to the normal life expectancy, but allowance must be made for obsolescence. Rates of 12 per cent and 8 per cent have been used where 200 tons and 50 tons per annum respectively are produced. These depreciation rates are not in exact proportion to annual hours worked because of the relative importance of obsolescence in equipment used for only a few weeks in each year. Depreciation on the storage shed(s) is charged at 5 per cent per annum.

Interest is charged at $5\frac{1}{2}$ per cent per annum on one-half of the capital cost on the items subject to depreciation, (*i.e.*, the machinery and the shed) on the reducing balance principle. If the machinery were bought on hire-purchase, as is common, a much higher interest rate would be chargeable.

[37] Amongst the gaps in our knowledge which were encountered in the discussion, the following are of particular importance:

- the relationships between stocking rate, wool production and rate of supplementary feeding (especially of conserved pasture);
- substitution relationships between grazed pasture and pasture hay;
- the quantitative effect on pasture growth and consumption of supplementary feeding;
- the measurement of the long-term effect on pasture production of pasture conservation of various intensities;
- the quantitative effects on stock of various types of special purpose feeding;
- the carrying capacity of grazed cereal crops and the effects on subsequent yields of various intensities of grazing;
- the loss of nutrients in hay during storage of varying duration.

Running Costs

These consist of the man-hours and the running costs of machinery in harvesting and the costs of twine, fire insurance and feeding out.

The man-hours and machine-hours per ton of hay set out in Table II are mainly based on 25 mail questionnaires so far returned. A close relationship between yield and cost seems apparent for mowing, raking and baling. Within limits, these operations take little more time in a heavy crop than in a light crop. Insufficient data has been so far received to establish reliable regression equations of yield on cost, but approximations have been made which are sufficiently accurate for present purposes. For example, in the case of mowing (6 ft. mowers) crops yielding 1.0 to 1.99 tons per acre cost, on average, 0.56 man-hours for an average yield of 1.37 tons per acre. The line of best fit suggests that a slightly higher yield—1.5 ton per acre—would involve slightly lower mowing costs per ton—approximately 0.50 man-hours. Man-hours include an allowance for maintenance and daily servicing of equipment, as well as time lost from breakdowns.

In picking-up, carting and stacking no allowance is made for a bale loader in the field or a bale elevator at the stack. A grazier conserving 200 tons of hay per annum might require these items, but there is evidence to suggest that their use may have little net effect on unit costs.[38]

A tractor running cost of 11s. per hour is assumed (medium power). This figure is based on a survey by Druce, adjusted roughly to 1959 prices.[39] The running cost for the truck is assumed to be 10s. per hour and is based, rather precariously, on contract rates.

"Hidden" Costs

An important "hidden" cost is the wastage that occurs in storage and in feeding out. This cost is very difficult to measure, and is likely to vary considerably between farms. It seems probable that for farmers of average efficiency storing hay in a well-constructed shed for less than two years, wastage would be within the range of 10-15 per cent. The figure of 15 per cent assumed in Table III is somewhat high relative to experimental results and to estimates made by survey farmers and agronomists (see Appendix IV).

Another hidden cost that might need to be considered in some situations is that of the soil nutrients removed in hay-making. Where an area is cut for hay very frequently, and especially where the hay is fed back elsewhere on the farm, or is sold off the farm, deficiencies of potash, sulphur or phosphorus may eventually necessitate expensive fertiliser application.

[38] "Report on a Study of Bale Loading and Stacking", *National Institute of Agricultural Engineering Report;* (Beds. England 1952).

[39] P. C. Druce, "The Cost of Operating Farm Machinery on Central-Western Wheat Farms", this *Review,* Vol. 19, No. 3 (September, 1951). Penny and Jarrett, *op. cit.* estimated the variable cost for a medium power kerosene tractor at 10s. 7d. per hour in 1956.

The immediate effect of hay cutting on regrowth would only need to be considered as a cost where the regrowth would have made a significant contribution to grazing outside the period of surplus feed supply.

Some cost, though relatively unimportant, is involved in the damage occasionally done by rain during harvesting. To make an estimate for "spoilage" would involve too many heroic assumptions, and for this reason it has been left out of account. As an illustration rather than an estimate: If rain spoiled one half of a crop once every four years (*i.e.*, one ton in every eight) and the spoilt crop was at the raked stage (mowing and raking costs approximately 16s. per ton, from Table II), a cost of 2s. per ton could be allowed for spoilage.

In areas where this would be an important cost, silage would be a preferable form of conservation. However, if the reader wishes to add his own estimate to the costs shown here, the approximate effect on profitability can be judged from Table VII or from varying the revenue equation given. The same applies to those who wish to make an allowance for the fertiliser cost necessary to offset the long-term effect on soil fertility of an intensive hay-cutting programme.

APPENDIX II

The Period of Feeding

As is shown in Figure 3, June was the most frequently mentioned month of feed shortage (mentioned by 33 graziers) followed by July (30), August (24), May (18), and April (16). A number of graziers made estimates of the period of feed shortage but declined to specify the months. A typical answer in these cases was: "Three to four months, but could occur at any time of the year, though most likely in autumn-winter".

The period of feeding following higher stocking will vary considerably between seasons. In good seasons, the additional stock will be carried comfortably with no hand-feeding. In poor seasons they may require full maintenance rations for most or all of the year, if their grazing is not to be at the exense of the initial flock.

The budget presented can be applied in areas where winters are less severe, and the main variations are between seasons. In these areas, however, the estimation of the average number of months of feeding per annum may be more difficult.

To judge on the answers received in the mail survey, there will be a considerable variation between properties in the duration of the average period of feed shortage. Part of the variation in answers given by graziers is no doubt due to inadequate knowledge. The question asked was certainly a difficult one. However, considerable variation is to be expected from different stocking policies, differences between farms in soil and topography, and different pasture varieties and stages of pasture development.

The period of feeding would naturally be affected by the magnitude of the increase in stocking, at least where the increase in stock carried was large in relation to property size. The graziers' estimates shown in Table

V are based on an assumed increase in the stocking rate of 25 per cent. Increases above 25 per cent would naturally tend to necessitate more frequent feeding in late summer, autumn and winter. However, on improved pastures it would require very large increases in the stocking rate, to eliminate the spring-early summer surplus, except in poor seasons, even allowing for a considerable proportion of paddocks being shut for hay. Nevertheless, the figures in Table IV, and the budgets based on these figures, are only applicable to a property of reasonable size.

On a 300 acre property, it could not be assumed that the conservation programme outlined would support the increased sheep numbers indicated, since the impact of the programme on the smaller property would be much greater than on the 1,000 acres assumed. Willoughby has shown that intensive fodder conservation with very high stocking rates can have a considerable effect on subsequent pasture performance.[40] However, on a farm of 1,000 acres carrying 2,000 sheep, an annual production of 100 tons of pasture hay would require the cutting of only 6.7 per cent of the property each year, and the resultant increase in stocking rate (assuming five months feeding and average efficiency) would be only 30 per cent.

APPENDIX III

The Level of Feeding

The level of feeding assumed must, of course, be discussed in relation to the wool cut per head. It is assumed that the additional sheep produce 9.5 lb. of wool per head, which is a conservative estimate of the average wool cut on well-improved Southern Tableland properties. No estimates are available of the autumn-winter level of nutrition on the Southern Tableland, but at normal stocking rates severe weight losses usually occur. The additional sheep fed 5.5 food units per week are unlikely to be receiving significantly less than the initial flock grazing meagre autumn-winter pastures. In the other six to eight months of the year—the period of "surplus"—they will be grazing the same pastures as the initial flock, and will presumably be growing wool at the same rate.

The term "surplus" refers solely to *quantity*. The *quality* of late summer-early autumn grazing is usually very low, except for brief periods after rain, but the quantity is frequently such that additional sheep could be carried without lowering the average grazing intake.

A series of experiments by Briggs, Franklin and McClymont provide some comparison.[41] In these experiments, using weaners and dry ewes, weekly feeding of 4 to 4¼ food units, mainly in the form of oats, produced wool at an annual rate of 6½ to 7½ lb. Admittedly, only good quality

[40] Willoughby, *loc. cit.*

[41] Briggs, Franklin and McClymont (1957) *op. cit.*; *Australian Journal of Agricultural Research*, Vol. 3, No. 2 (April, 1952), p. 168-186; *Australian Veterinary Journal*, Vol. 32, No. 11 (November, 1956), p. 299-303.

grass-clover hay has a protein equivalent as high as oats. Nevertheless, the assumed cut of $9\frac{1}{2}$ lb. per head seems reasonable in relation to these results, taking into account:

(i) The higher starch equivalent of the assumed ration;

(ii) The fact that the wool production of the additional sheep will be at a much higher rate in the six to eight months outside the period of feeding. This results not only from the abundant high quality feed in the spring-early summer, but from the fact that temperature is an important determinant of wool growth. Ferguson, Carter and Hardy have shown that merinos fed on a uniform maintenance diet have a maximum summer growth rate of wool 44 per cent higher than the minimum winter growth rate.[42]

APPENDIX IV

Wastage

Apparently there have been no Australian experiments published on losses of nutrients in hay during storage. However, to judge on overseas experiments and on farmers' estimates, wastage during short-term storage is not likely to exceed 10 per cent given reasonable efficiency and a soundly constructed shed.

In seven United States and United Kingdom experiments consulted, losses of dry matter in storage ranged from 3.5 to 6.5 per cent, with losses of starch equivalent of a similar order wherever measured. In one other experiment, losses of dry matter were 8.9 to 12.9 per cent. The period of storage in the three experiments where this was reported was around six months.[43]

Several specialists on fodder conservation who have been consulted were of the opinion that similar experiments under Australian conditions would yield lower percentage losses than those quoted above. One CSIRO

[42] Ferguson, Carter and Hardy, "Comparative Fleece Growth in Sheep", *Australian Journal of Scientific Research,* Series B, Vol. 2 (Melbourne: CSIRO and Australian National Research Council, 1949), p. 41.

[43] S. J. Watson, Ferguson and Horton—"Time of Cutting Hay and Losses During Haymaking", *Journal of Agricultural Science* (England), Vol. 27, Part 2, p. 253-4 (1937).

E. J. Hoffman and M. A. Bradshaw, Losses in Spontaneous Heating of Alfalfa Hay," *Journal of Agricultural Research* (United States), Vol. 54, No. 3 (February, 1957), p. 159-184.

F. B. Morrison, *Feeds and Feeding* (21st Edition; Ithaca, New York: Morrison Publishing Co., 1951), p. 295.

O. M. Camburn, H. B. Ellenberger, C. H. Jones and G. C. Crooks, "The Conservation of Alfalfa and Timothy Nutrients as Silage and as Hay", III, *Vermont AES Bulletin* 509 (1944).

R. E. Hodgson, J. C. Knott, V. L. Miller and H. K. Murer, "The Nutritive Value of Home Grown Roughage Rations for Dairy Cattle", *Washington AES Bulletin* 366 (1938).

E. O. Pollack and W. H. Hosterman, "Hay Quality", *USDA Miscellaneous Publication* 363 (1939), p. 32.

References to experiments by Truninger (p. 910) and Woodward and Shepherd (p. 911) are reported in C. H. Huffman. "Roughage Quality and Quantity in the Dairy Ration", *Journal of Dairy Science,* Vol. 22 (1939).

experiment in Victoria currently being conducted has shown a loss of 3.7 per cent after 7.5 months storage. Even lower losses have occurred in an unpublished experiment recently conducted by the Victorian Department of Agriculture at Glenormiston.[44]

The only other figures available for losses in shed storage under Australian conditions are estimates, presumably not very accurate, obtained from Yass Valley survey farmers and from the mailed questionnaire. Of the 47 estimates made of losses after two years storage, 37 were under 5 per cent.

Hay stored in stacks, as distinct from sheds, can suffer heavy wastage. Most of the twenty-three Yass Valley farmers who stored hay outside a shed declined to estimate wastage but estimates that were made included six within the range of 20 to 50 per cent. Departmental agronomists consulted suggested that if one excludes the well-constructed stacks, which are rarities, 25 to 50 per cent of all hay stored in stacks is wasted. If these estimates are accurate, the cost of shed storage at approximately 6s. 3d. per ton per annum is well justified.

The losses involved in feeding out would vary from virtually nil when palatable hay is fed on hard ground to hungry sheep in calm weather, to very high losses of unpalatable hay fed on to the ground in wet windy weather.

[44] E. K. Simmons, *private communication.*