PASTURE IMPROVEMENT—THE FARMER'S ECONOMIC CHOICE *

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The economic choice confronting the farmer or grazier who is considering a pasture improvement programme can be considered under two headings: (a) how profitable is such an investment? and (b) what is economically the best way of going about it? Whilst the second question is logically prior to the first, it will be convenient to treat them here in reverse order. To some extent the grazier's approach may correspond to this order, for it is usual to consider whether to make a certain investment or improvement before determining in detail how to go about it.

(a) *The Profitability of Pasture Improvement*

While motives for investment will vary widely, the economist's criterion of the profitability of an investment compares the additional net income produced with the amount of money originally invested. Two comparisons of this type are possible. In both cases we are confronted by a stream of money flows (both positive and negative) over time. Let the net money flow in year m (i.e. receipts minus capital and running expenses) be denoted by x_m. Different investments will give rise to different rates of net money flow. If the net money flows from investment A always exceed those from investment B (i.e. in each individual year) A is obviously preferable to B. However, it is not difficult to imagine that this criterion is not of wide applicability. What happens if the money flows resulting from investment A are greater in some years and less in others than those from investment B? We must find a means of combining the value of money flows in year m and in year m+1. As money not invested in pasture improvement in year m need not be borrowed until year m+1 (or can be invested elsewhere) an equivalence relation can be provided by the rate of interest on borrowing (or lending). We can therefore add our stream of money flows as shown below:

$$x_1 + \frac{x_2}{1+r} + \frac{x_3}{(1+r)^2} + \cdots\cdots\cdots + \frac{x_n}{(1+r)^{n-1}} = k \quad \ldots\ldots (1)$$

where n = length of life of the investment and r = the rate of interest.

The two comparisons possible on the basis of these streams of money

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flows or incomes depend on whether the rate of interest is regarded as given or not. According to the first type of comparison we compute the present value of such an investment (i.e. k in the above equation);[1] using a given rate of interest—namely the rate at which money can be borrowed or at which it can be invested outside the enterprise. If the present value is positive, the investment should be undertaken. If an entrepreneur is considering the relative profitability of two or more investments he should undertake the one giving him the highest present value per £ of discounted money outlay in the initial years of the programme.

The second type of comparison involves the solution of a similar type of equation to the first—except that k is made equal to zero and the equation is solved for r.

i.e.

$$\sum_{1}^{n} \frac{x_n}{(1+r)^{n-1}} = 0 \qquad \text{(2)}$$

All investment possibilities are ordered according to the value of the rate of return they can generate. The entrepreneur's aim—according to this type of comparison—is to maximise the internal rate of return.

While these two measures of profitability are quite distinct and can, theoretically, give different results, it is rather unlikely that they will give rise to a different ordering of investment possibilities in the type of problem we are considering. In this paper both measures of profitability will be used. In the present section the internal rate of return obtainable from pasture improvement under a variety of situations was computed. This measure was preferred in the present context as it makes a comparison of the profitability of pasture improvement with other forms of investment (both within and outside agriculture) more realistic. In the following section the present value method has been used because it provides directly a monetary estimate of the marginal product of different limiting resources.[2]

Table 1 gives the estimated long-term percentage return on capital invested in pasture improvement for the few cases where detailed financial budgets could be obtained. It is desirable to describe the approximations which were necessary to derive the estimated percentage

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[1] This formulation differs from the normally accepted method of computing the present value which *excludes* the initial capital investment. One reason for defying common usage is that in the case of pasture improvement the initial investment is spread over a number of years—which means that capital outlays as well as net revenue need to be discounted. In addition it is often difficult to separate capital costs from running expenses—although this somewhat arbitrary distinction will be used at times in the succeeding discussion. It is therefore desirable to use the formulation given in equation (1) instead of the more common "present value" formula which excludes initial capital outlays.

[2] Since this paper was written, a check on eight of the eleven budgets of Table 1 showed that discrepancies are more likely to arise than was believed earlier. When grouped in order of increasing profitability according to the criterion of the internal rate of return, these budgets run: K (i), E, A, K (ii), B, C, F, D. If grouped according to the present value of the investment (where the rate of interest is taken at 10%) the order becomes: A, K (i), E, B, D, K (ii), C, F.

Theoretically, the rating of the profitability of investment projects according to the internal rate of return seems more correct. However, this issue cannot be discussed adequately in a relatively short footnote.

While it was not possible to repeat the linear programming calculations in the second section, using the criterion of the internal rate of return, the validity of the general argument of that section is not affected, even though some of the optimum programmes could be.

return. In the case of the actual farm budgets (Farms A-F in Table 1) information on seasonally corrected production increases was available only until 1955-56; i.e. for a period ranging from 6 to 17 years after the pasture improvement programmes were started on these farms. The productivity of pasture usually increases for some 3 to 4 years after sowing and may increase in subsequent years (usually at a distinctly slower rate). It is likely, therefore, that there will be some further production increases on Farms A-F in the future (without any additional investment) as 9% of the sown pasture acreage on these farms was only one year old and 30% less than three years old. It was not possible to estimate these likely future increases and it was necessary to assume that the net income obtainable in future years equalled that in 1955-56. On the other hand underestimates in net incomes ten years or so after the improvement programme started exercise a minor influence on the estimate of the long-term percentage rate of return. Another source of underestimation (on Farms B-F) is that only increases in wool production have been obtained; changes in stock sales due to pasture improvement could not be separated from changes resulting from seasonal fluctuations. Probably 90% of the increased income resulting from pasture improvement on these farms would be obtained from extra wool production.

Omissions which would tend to exaggerate the profitability of pasture improvement on Farms B-F are: (a) additional livestock expenses (shearing, crutching, etc.). These would be a comparatively minor item in total costs; (b) additional marketing expenses for wool (freight, cartage, insurance, wool packs). These would amount to approximately 6d. per lb. (and could be taken into account by assuming that the estimate of profitability relates to a price which is 6d. above the average 1955-56 level); (c) purchases of livestock in the early years of an improvement programme. Campbell and Shand's evidence on stock changes suggests that these were not of major importance for Farms B-F. These omissions would be counterbalanced by the consideration that some of the ancillary capital investment on these farms was stimulated by high prices in the post-war decade and by accelerated depreciation allowances and may not have been absolutely necessary to obtain the recorded increases in production.

Campbell and Shand's depreciation figures—which ignore the special allowances available for tax purposes—were used to obtain net income figures for 1955-56 and for subsequent years. Furthermore the assumption was made that the average repair costs of plant, machinery and structures would equal the allowance for depreciation.[3]

It will be seen, therefore, that the information on the profitability of pasture improvement is subject to a great many qualifications. It should, however, give us a broad estimate of the percentage rate of return on capital invested in pasture improvement under farm conditions. Comparisons of profitability under different conditions may also throw some light on the reasons for the variations obtained.

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[3] It may be desirable to give an example of the equation used to estimate the percentage rate of return. For Farm C the equation was: $-250-1672x-1825x^2-1750x^3-1628x^4-2465x^5-454x^6-7144x^7+2953x^8+5071\ (x^9+x^{10}+ \ldots\ldots\ldots +x^{49}) = 0$ where $x = 1/1+r$. 50 years was taken purely for computational convenience. r_∞ exceeds r_{50} by $\frac{1}{4}$% or less in cases A-J. For K (with extra labour) the difference may be somewhat greater.

Table 1

THE ESTIMATED PROFITABILITY OF PASTURE IMPROVEMENT

Farm No.	*Location*	*Estimated (compound) rate of return on investment**	*No. of years before receipts exceeded costs†*	*Capital investment*** per acre of improved pasture	*Extra gross income††* per acre of improved pasture	*Extra net income* per acre of improved pasture	*Information based on:*
		%	No.	£	£	£	
A	Oberon Shire, Central Tableland, N.S.W.	8	12	30.8	7.15	4.96	Single farm case studies; farmers' records.
B	Molong Shire, Central Western Slope, N.S.W.	14½	8	9.4	2.67	1.18	
C	Bibbenluke Shire, Southern Tablelands, N.S.W.	18	8	6.8 – 10.1	2.46 – 3.66	1.59 – 2.37	
D		25½	4	6.2 – 7.7	1.86 – 2.27	.35 – .44	
E		8	10	7.9 – 9.5	1.89 – 2.27	.89 – 1.07	
F		23½	7	12.2	6.29	4.80	
I without extra labour	Northern Tablelands, N.S.W. (Aerial Pasture Improvement).	21½	4	4.0	3.24	1.79	Average of 13 farmers, farmers' estimates and records.
I with extra labour		16	5			1.29	
J without extra labour	South and Central Western Slope, N.S.W.	19½	8	4.5 – 6.8	4.53 – 4.72	1.88 – 2.82	Average of 71 farmers' estimates.
K without extra labour	Upper South-East. S.A.	14¼	6	19.5	4.2	1.44	Personal experience of large-scale development in the area.
K with extra labour		5¾	5			3.37	

* Method of estimation explained in the text.

† In the case of Farm B receipts exceeded costs in years 4 and 5; but costs exceeded receipts in the next three years. For D costs also exceeded receipts in year 8. For F receipts just exceeded costs in year 5, but there was a substantial deficit in the following two years.

** For Farms A-F capital investment up to 1954/55 divided by acreage under sown pastures in 1954/55.

†† For Farms A-F gross income in 1955/56 divided by acreage under sown pastures in 1954/55. The alternative figures for C, D and E arise because some pre-war pasture sowings on these farms had persisted without superphosphate applications during the war. The alternative figures on these farms are based on two limiting assumptions: (a) the increase in income per acre of pre-war sown pastures was the same as the post-war sown pastures and (b) there was no increase in income per acre of pre-war sown pasture on such farms. For Farm J the alternatives are based on whether areas temporarily under wheat—but part of an improved pasture rotation—are treated as "improved pastures" or not.

Sources of data:

Farms A-F: *A Study of the Economics of Pasture Improvement on Selected Farms in N.S.W.* by R. T. Shand (unpublished M.Sc. thesis—Fisher Library, University of Sydney). A revised and abbreviated version has been published as: *An Economic Study of Pasture Improvement on Some Farms in N.S.W.* by Keith O. Campbell and Richard T. Shand. Mimeographed Report No. 2, Department of Agricultural Economics, University of Sydney, 1958.

I: "Aerial Pasture Improvement in New South Wales" by F. H. Gruen and R. A. Pearse, *Review of Marketing and Agricultural Economics,* vol. 26, No. 2 (June, 1958).

J: "Financial Aspects of Pasture Improvement on Southern Wheat Sheep Farms" by F. H. Gruen, *Review of Marketing and Agricultural Economics,* vol. 24, No. 4 (December, 1956).

K: "Land Settlement in Australia" by W. Edgerley, *Proceedings of Bankers' Residential Conference on Pasture Improvement and Land Development,* May, 1958.

While the long-term rate of return in Table 1 ranges from less than 6% to more than 25%, in eight of the eleven budgets the rate of return exceeds 14%. While this confirms the popular notion that pasture improvement has been a fairly profitable investment—even at the relatively low wool prices of 1955-56—the return on capital is not as spectacular as outside observers (including the writer) have sometimes believed. One would presumably require a return of at least 10% when the long-term nature of the investment and the special risks of production and price uncertainty in woolgrowing are taken into account.

On the other hand the percentage return from pasture improvement is probably considerably greater than that which can be obtained from the purchase of extra land—often the only alternative method of raising farm income.

Two of the hypothetical budgets (i.e. I and K) have been worked out on the basis of two assumptions; the first of these is that the farmer can cope with the extra work involved without an increase in his labour force. (This is a limiting assumption likely to be correct for small increases in stock numbers and pasture sowings on many farms.) The second assumption—labelled "with extra labour" in Table 1—is that the farmer needs an extra permanent man to look after an additional 1500 sheep. Under these conditions the percentage rate of return is obviously lower than when no extra labour is required.

There are two main reasons why the rate of return is somewhat lower than one would expect at first: (i) While the costs of actual pasture improvement (i.e. seed, fuel and repairs for machinery, fertilisers, etc.) are small by comparison with the increase in the value of extra output, a variety of other expenses are incurred which sometimes greatly exceed the direct costs of pasture improvement. (ii) There is a fairly long time lag before the investment yields anything like maximum physical response. This lag is accentuated where the improvement of a given area has to be staggered over a number of years because of labour and money shortages—as in the case of the normal farm situation. (Aerial Pasture Improvement—i.e. Case I—is a partial exception there, as labour shortages at critical times of the year are unlikely to be of significance.)

Comparison of the profitability on different farms (i.e. Case studies A-F) produces some surprising findings. The highest percentage rate of return on capital was actually obtained on Farm D where the long-term additional net income per acre was by far the lowest. This seems to be due partly to a relatively rapid build-up in production after pasture improvement started and, perhaps more importantly, that D's comparatively low capital expenditure per acre of improved pasture was postponed for four years by borrowing plant. This meant that he had a relatively small initial capital outlay on which a large percentage return was obtained over the estimated life of the investment. Purchase of plant and investment in structural improvement in later years was paid for out of the increased earnings obtained. Encouragement of "borrowing" of plant on a large scale would therefore seem to be one way of raising the profitability of pasture improvement! While this may sound facetious, it probably is true that the capital investment in plant in the early years of a pasture improvement programme imposes a heavy financial burden on farmers which it may be advisable to postpone by obtaining contractors to carry out some of the initial work.

Farm F is perhaps a more typical success story where high returns on capital are largely attributable to the high gross and net productivity per acre obtained—probably largely by good management. Farm A on the other hand, with the highest net income per acre, obtained one of the poorest financial results. In this case the reasons are fairly obvious. A's capital investment was far in excess of what would normally be required. It included almost £10 an acre clearing costs plus an unusually heavy expenditure on buildings, fencing and machinery. Probably another major factor reducing profitability was that the improvement programme commenced in 1939-40. Subsequent shortages of fertiliser slowed down the resultant growth in output.

The hypothetical farm budgets I and J suggest that similar rates of return to those obtained by Campbell and Shand's graziers in the Southern and Central Tablelands can be expected in other parts of New South Wales. Farm budget I relates to Aerial Pasture Improvement in the New England District of New South Wales and J to ground methods in the South and Central Western Slope Divisions of the N.S.W. wheat belt. Budget K for the South-East of South Australia suggests that the profitability of pasture improvement in this area depends largely on whether it can utilise labour which is otherwise not fully occupied. It tends to confirm the views of Dr. A. R. Callaghan, the former Director of the South Australian Department of Agriculture, who argued that the investment in pasture improvement on existing farms might well prove to be more economical than the more spectacular large-scale development programmes which convert a semi-scrub desert area into fertile pasture lands.

(b) *The Optimum Pasture Improvement Programme*

Having made up his mind to undertake a pasture improvement programme, a grazier has to decide on the best programme—i.e. the most profitable in this context. He can vary the area he sows annually, the quantity of fertiliser per acre, the type and quantity of seed, the cultural methods used, etc. These questions are often treated as purely agricultural problems. While it is true that the technical information needed to answer these questions is obtained by agricultural scientists, basically they are of an economic nature—namely how to maximise long-term net income given certain physical and technical restrictions. Agricultural scientists in Australia have made great strides in tackling a large number of fundamental problems—for instance, in the field of plant nutrition. But very little detailed experimental work has been done to follow up these basic studies. Extension advice to farmers is based, by and large, on a few fundamental experiments designed to yield, not quantitative information for use by farmers, but mainly qualitative data useful for the research worker who is interested in certain fundamental relationships such as that between plant growth and the supply of certain minerals.

(i) *The Optimum Application of Fertiliser*

The optimum application of superphosphate to pastures is a good example of the absence of this type of applied research work. To the best of my knowledge no experiment has ever been conducted in New South Wales (and possibly not anywhere in Australia) specifically designed to measure the optimum application of fertiliser per acre of pasture. Admittedly the problem is a difficult one; the optimum application may depend on the previous fertiliser history of the country; it will certainly vary from one soil type to another and according to changing seasonal conditions. Lastly it is difficult to measure pasture output in meaningful economic terms without the use of grazing animals—which would make such an experiment expensive. But when one considers the economic importance of such information to farmers and the length of time we have been experimenting with pastures this seems an astonishing gap. As superphosphate purchase and application is the largest annual cost item in pasture improvement it would surely be worth while to examine this question. Nor does it seem likely that the losses resulting from our lack of detailed knowledge on this issue are minor and purely marginal. If the elasticity of the fertiliser response curve at the point of farmers' average use per acre is near unity, as some experiments or demonstrations have suggested, major inefficiencies exist.[4] (Annual incomes could then probably be increased by an amount of the order of 10/- to £1 per acre of improved pasture where additional areas are still being sown.)

A similar (though less strong) case can be made out for detailed experimental work aimed to give farmers information of the differences in output resulting from the use of some of the more expensive grasses (e.g. *Phalaris tuberosa*) which are advocated by extension officers on many of the more fertile soils.

(ii) *The Optimum Method of Improvement*

A grazier can use a wide variety of mechanical or cultural methods to establish pastures. The most intensive requires ploughing, frequent discings, or other workings to establish a reasonably fine, moist seedbed into which the seed is dropped. A second method involves the surface introduction of the seed into the natural pasture sward by using a combine or drill. This is considerably faster, cheaper and usually produces a somewhat smaller increase in feed production per acre. There are obviously a number of intermediate methods of establishment —not as thorough as a prepared seedbed but yet more intensive than combining. A third method involves the broadcasting of fertiliser and pasture seed on the native grass cover—without securing any soil cover for the seed. Either ground methods (trucks or tractors) or aircraft can be used for broadcasting. This method is even cheaper per acre, but production responses are riskier, slower, and, on the whole, smaller than when a combine is used.[5]

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[4] The economic loss depends on the size of the discrepancy between the price ratios and the marginal product ratios at the farmers' rate of application. In the case of wheat there is some evidence from New South Wales Department of Agriculture trials to suggest that the economic loss is comparatively small (around 5-10% of net income per acre); in the case of pastures far greater losses are suggested by the limited information available for some areas—e.g. at Carrick, Southern Tablelands, and Glen Innes, Northern Tablelands, N.S.W. c.f. "Superphosphate Use in New South Wales" by F. H. Gruen, *Review of Marketing and Agricultural Economics,* vol. 23, No. 1 (March, 1955), pp. 15-26.

[5] For a more detailed description of these methods, discussing their relative advantages and disadvantages for the New England Region, see: *Economics of Pasture Improvement* (Roneoed), Bureau of Agricultural Economics, November, 1956, pp. 9-11.

In many cases the choice of the optimum method of pasture establishment is simple—the advantages of one particular method are outstanding. For instance, on arable land in the wheat belt practically all pasture except lucerne and phalaris is sown with a cover crop of cereals. This produces a cash return which more than pays for cultivation costs but does not interfere markedly with the establishment of the pasture. To go to the other extreme, on semi-cleared rough country which cannot be covered with ground implements, aerial broadcasting of fertiliser and seed are obviously necessary.

However, there are many cases where the choice is by no means clear cut. This again is a problem deserving more attention experimentally than it has received. Reading the extension literature on pasture improvement, one is struck by the implicit assumption that the best method of pasture improvement under any conditions is the most intensive which can be used on the particular soil type. In other words if the country is level and the soil deep enough, the most intensive method is almost invariably recommended. It is contended that "surface scratching" (i.e. by using drill or combine only) should be confined to areas where shallow top soils predominate and broadcasting to those sections of the farm which are too steep for the use of tillage implements.

This is surely too simple a view of the best choice available to a farmer or grazier who has a number of different resources which may limit the growth of his output or income.

Placing such emphasis on maximising production per acre is only justified under certain narrowly defined conditions, which are that:

(i) improvable land is THE factor limiting production growth or

(ii) the most intensive technique maximises not only production per acre but also production per unit of other scarce resource (e.g. money or labour). In other words that it is the cheapest method per unit increase of (discounted) net income.

The first condition is rarely fulfilled. In most cases farmers are limited by shortages of finance or labour. Reluctance to lower stock numbers while newly established pasture has to be protected from grazing is also sometimes given as a reason for limiting the area to be improved at any one time. (This can be interpreted either as a land or capital restriction.) Whether the second condition holds is difficult to say, as there is scant empirical data regarding the production responses to the different methods of pasture establishment. In some areas—where the risk of failure is great—the most intensive method (which minimises this risk) is likely to be the cheapest method. In areas where climatic risks are smaller, less intensive methods may be most profitable.

Even within a uniform climatic region and on one soil type the same method of establishment may not be the best for all farmers. This is partly because of differences in the pre-improvement position of individual farmers and partly because of variations in their possible factor combinations. Thus a farmer owning a larger tractor than another (enabling him to work a bigger area per day) may find it profitable to use a more intensive method. Perhaps of more importance is the state of timber cover. Where substantial clearing expenditure per acre is needed to enable a seedbed to be prepared, less intensive methods may be more profitable. Unless farmers are given some information about the difference in response as a result of using various methods it is impossible to estimate the critical level of clearing costs—i.e. the point at which one method becomes more profitable than another.

What is perhaps not so well recognised is that in many cases graziers may not be interested in the cheapest method (per unit increase in output or income) but in the method which produces the largest income per unit of some scarce resource. For instance, while a pasture improvement programme will require not only a certain amount of money but also land and the use of extra labour, the limiting factor may be the availability of money. This assumes that any "surplus" labour and land cannot be readily converted into more money—a plausible assumption in many cases. While it is less likely that "surplus" money cannot be used to hire experienced labour, in certain situations labour (and machine services) could also be limiting. Reliable contractors are often not available at the right time and hiring labour without machinery would be of little value. Similarly land can sometimes be a limiting factor.

These differences can lead to significant variations in the optimum method of improvement. The effect of such differences in factor availability on the optimum method of pasture improvement can best be examined by the use of linear programming. Briefly linear programming enables us to choose the best combination of activities (i.e. pasture improvement programmes) subject to certain restrictions (namely that the maximum amount of money or labour used in a given year is less than or at most equal to the quantities available). The use of a simple example to illustrate the formulation of the problem may be advisable before discussing a more realistic (and more complicated) case.

Take a farmer who wants to maximise the increase in his sheep flock. Say he has two means available—one intensive method of improvement and one extensive. Let the land, capital and labour requirements of the two methods be as given in Table 2.

Table 2

RESOURCE REQUIREMENTS OF DIFFERENT IMPROVEMENT METHODS

Resource	*Activity*		*Quantity of Resource Available*
	Intensive	*Extensive*	
Labour	3	1	75 days
Money	2	1	£60
Land	1	1	50 acres
Increase in sheep numbers	2	1	

The problem can then be stated as follows. We want to find the area of intensive (x_1) and/or extensive (x_2) methods which will maximise the increase in sheep numbers, (z)

$$\begin{array}{ll} \text{i.e.} & z = 2x_1 + x_2 = \text{maximum} \\ \text{subject to} & 3x_1 + x_2 \leqslant 75 \\ & 2x_1 + x_2 \leqslant 60 \\ & x_1 + x_2 \leqslant 50 \end{array}$$

In this simple case the problem can be solved by trial and error or graphically. The optimum combination of activities involves the improvement of 15 acres by the intensive method and of 30 acres by the other method. This will enable an extra 60 sheep to be carried. Any other combination of x_1 and x_2 which does not violate the restrictions set up, will produce a smaller increase.

Now assume we have £62 instead of £60 available for improvement—the other conditions remaining unchanged. The optimum combination then involves the use of 12 acres of the intensive method and 38 acres of the extensive method—enabling sheep numbers to be increased to 62. Hence for each additional £ available in the first situation one additional sheep can be carried—i.e. the marginal product per £ is one sheep—over the range from £60 to £62.

This is basically the approach which has been applied to examine the optimum pasture improvement programme under more realistic conditions. For our example we have taken a hypothetical farm near Armidale in the New England District of New South Wales on basalt soil similar to that at Chiswick Experiment Station. Four improvement methods were considered—using a prepared seedbed, combining, broadcasting fertiliser and seed by ground methods and lastly by aircraft. The input-output data used were based on surveys of pasture improvement in the area and experimental results from Chiswick Experiment Station. The data used are given in the Appendix. While great accuracy cannot be claimed for them, they are the best which would be available to a farmer in the area faced with this problem.

It was assumed that the farmer owned a Ferguson tractor (or one of similar size) plus the usual set of farm implements (plough, disc harrows, combine, fertiliser distributor). The limiting factors were land, labour over a 10-year period and money over a seven-year period. For each of the four pasture improvement methods considered, four different commencing years were allowed, making a total of 16 different possible activities. The restrictions used were varied systematically to find the effect of changes in the availability of land, labour and money on the optimum programme. Two of these three variables had to be held constant in each case to estimate the change resulting from the variation of the remaining one. The constant values used were 600 acres for land, an initial sum of £1000 and 18 days for labour.[6] (It was originally believed that labour might be limiting in two periods—February/March, when new pasture is sown, and October/November, when sheep are shorn and land is ploughed up for a prepared seedbed; however, examination of the matrix showed that the February/March restriction was dominant. Eighteen days rather than a longer period

[6] It was assumed that whatever money was not used in Year 1 could be used in Year 2; what was not used in Years 1 and 2 could be used in Year 3 and so on. Any net income obtained from pasture improvement before Year 7 was assumed to be available for re-investment in a pasture improvement programme—either in the year in which such net earnings were made or in any succeeding year.

was used as the grazier still has his ordinary sheep work to do. As this figure is varied, the exact value placed on it is not crucial.)

It was postulated in the simpler example that the farmer tried to maximise the increase in sheep numbers. This was actually the original maximisation criterion included in the programme. However, the use of this criterion soon proved unworkable—for the increase in sheep numbers is not only a function of the amount and method of pasture improvement used, but also of the year in which one tries to maximise sheep numbers. It was found that the optimum programme required to maximise sheep numbers in Year 5 differed markedly from that maximising sheep numbers of Year 10.[7] It was therefore decided to use an economic criterion which, while unfamiliar to the layman, has the virtue of consistency. This is the present value of the investment given in equation (1). The wool price used was 5/- per lb. net of marketing charges (freight, commission, insurance, etc.). This price is about 6d. below the average price ruling for New England wool in 1955/56 and 1957/58, but 6d. to 9d. above average 1958/59 prices. The rate of discount used was 10%.[8]

Changes in the Optimum Programme as Available Factor Proportions Change

The effect of varying the supply of land, labour and money on the optimum method of pasture improvement is shown in Tables 3, 4 and 5. The limiting resources, the present value of such investments and the marginal product per unit of variable resources are also given.

As one would expect, when land is particularly short (Table 3) the most intensive method—namely, use of a prepared seed bed in Year 1—is the most profitable technique. When 128 acres of pasture are sown in the first year with a prepared seed bed the £1000 available will be used up at the end of Year 3. If more land is available for sowing pasture it becomes profitable to reduce the area of prepared seed bed and substitute some combining in Year 1. This method has a peak money requirement in Year 4, when some surplus becomes available from prepared seed bed sowings in Year 1. Thus when 170 acres of land are available the optimum programme involves the sowing of 114 acres by a prepared seed bed and 56 acres by combining in Year 1.

If more than 170 acres are available to the farmer (plus £1000 and 18 days of labour), combining in Year 1 gradually replaces the prepared seed bed method completely. For each additional acre which becomes available, it then pays to increase combining (Year 1) by 1.85 acres and to reduce prepared seed bed (Year 1) by .85 acres. The reduction in the latter is necessary to provide the extra money—in

[7] The relevant optimum programmes are given in Table 8 in the Appendix. In addition there is a more fundamental reason why one should not use the increase in sheep numbers as a criterion; namely that this would imply that increases in sheep numbers are perfectly correlated with increases in net incomes (for the year in question). As the more intensive methods involve lower cash costs (mainly fertiliser) per additional sheep, this correspondence does not hold; hence intensive methods are preferable to extensive methods if there is no difference in the extra number of sheep carried by means of two different pasture improvement programmes.

[8] It was decided to depart from the normal convention of using the government long-term bond rate of 5%. Eight per cent. can be earned on long-term unsecured notes with many medium-sized companies. This does not as yet make any allowance for the special price and production risks of rural investment. An arbitrary 2% has been added for these additional risks.

Table 3

THE OPTIMUM PASTURE IMPROVEMENT PROGRAMME

(When the area of land is varied and the price of wool is 5/- a lb.)

Resources Required	*Prepared Seed Bed Year 1*	*Combining Year 1*	*Combining Year 2*	*Combining Year 3*	*Combining Year 4*	*Limiting Resources*	*Present Value*	*Marginal Product Per Acre*
Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*		£	£
127.7	127.7					Capital Year 3	2918	22.9
170.0	113.7	56.4				Capital Years 3 & 4	3681	18.0
303.0	—	303.0				Capital Year 4	5821	17.4
344.9	—	242.5	102.4			Capital Years 4 & 5	6443	14.8
455.9	—	286.0	—		169.8	Capital Years 4 & 5	7929	13.4
486.4	—	258.7	—		227.7	Capital Years 5 & 7	8233	10.0
520.1	66.0	112.6			341.5	Capital Years 5 & 7, Labour Year 4	8564	9.9
530.8	102.5			84.7	343.5	Capital Years 5 & 7, Labour Year 4	8602	3.6
	No further increase in present value possible (unless labour and/or capital resources increased).							

Year 3—for combining in Year 1 to be expanded. When 303 acres are available, the most profitable process is combining in Year 1. If more than 303 acres are available, the addition of combining in Year 2 becomes profitable. But combining in Year 2 uses some of the scarce money supplies of Year 4; hence some decline in combining Year 1 becomes necessary.

It is not proposed to trace through all the information supplied in Tables 3, 4 and 5 in this manner; with the help of Table 3 of the Appendix giving the resource requirements and maximising values used the interested reader will have little difficulty to ascertain why the different activities become the most profitable combinations at different stages.

But some additional features of the tables should perhaps be mentioned. A surprising finding is that the use of the most intensive method becomes one element of the most profitable combination of improvement methods when relatively large areas of land are available to the farmer (i.e. more than 486 acres in Table 3). The reason for this apparent paradox is that this combination of activities makes better use of the then scarce money resources. The prepared seed bed method builds up wool production and income more quickly, thus enabling more money to be used for pasture improvement in later years than if a more extensive (and slower) method were used. This is also brought out in the early section of Table 4 when little money is available for use with standard quantities of land and labour. As the amount of money increases combining in Year 1—which makes better use of labour—replaces the prepared seed bed method. If unlimited amounts of money were available for use in conjunction with the stated amounts of land and labour, £2997 would be invested at an interest rate of 10%. Beyond this point no increase in present value is possible.

Table 5 shows that aerial methods become profitable only when labour is very short. Since the cost of labour (plus the relevant machine services) is unlikely ever to be as high as the imputed marginal product, it seems reasonable to assume that there are few situations—on level land, with own machinery—when aerial methods would be optimum.[9]

[9] Some further comment regarding the marginal products for each of the variable resources of Tables 3, 4 and 5 seems desirable. The marginal product of land in Table 3 does not measure how much it would be profitable for a farmer to pay for extra land, given his present resource combinations. This is because the marginal product as defined in this context includes only the extra product resulting from pasture improvement. To this should be added the "additional net product" obtained from land in its non pasture-improved state. (This would probably add of the order of £10 per acre to the value it would pay a farmer to bid for such land.)

The marginal product per £100 in Table 4 is the highest marginal product—in those cases where money was limiting in more than one year. The marginal product per day in Table 5 is again the highest marginal product—where labour was limiting in more than one year. Throughout Table 5 the marginal product per day is extremely high. While it is a well-known phenomenon in agriculture that labour shortages at certain critical times of the year may be crucial—which is merely another way of saying that, at these times, the marginal product of labour is very high—it is possible that our formulation of the problem has involved some oversimplifications which have raised it above its "real" level.

As labour in periods other than February and March was not limiting, it was implicitly assumed to be costless; such an assumption would raise the marginal product of labour in February/March. Also deductions for variable costs per sheep—at 10/- per sheep for shearing, marketing, freight and chemicals—may have been insufficient. Lastly the marginal product per day refers not only to labour but also to tractor services, etc. However, when some allowances are made for these factors, the conclusion remains that the marginal products obtained are much higher than one would expect.

Table 4

THE OPTIMUM PASTURE IMPROVEMENT PROGRAMME

(When the amount of money available is varied and the wool price is 5/- a lb.)

Resources Required	*Prepared Seed Bed Year 1*	*Prepared Seed Bed Year 2*	*Prepared Seed Bed Year 3*	*Combining Year 1*	*Combining Year 2*	*Combining Year 3*	*Combining Year 4*	*Limiting Resources*	*Present Value*	*Marginal Product Per £100 Capital*
£	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*		£	£
828	96.7						355.1	Capital Years 5 & 7, Labour Year 4	7299	882.0
1039	103.8					103.9	340.9	Capital Years 5, 6 & 7, Labour Year 4	8897	754.5
1162	90.7			51.2		124.4	331.7	Capital Years 5, 6 & 7, Labour Year 4	9772	712.7
1202	30.0			242.5		—	325.5	Capital Years 5 & 7, Labour Year 4	10008	593.2
1233	—			319.0		—	281.0	Capital Year 5, Land	10155	466.3
1316	—			376.5		—	223.5	Capital Years 4 & 5 & Land	10435	338.9
1718	—			419.6	169.1	—	11.3	Capital Years 4 & 5 & Land	11168	182.3
1732	—			419.6	174.0	6.4	—	Capital Years 4 & 5 & Land & Labour Year 1	11193	173.5
1741	—			419.6	180.4	—	—	Land, Labour Year 1, Capital Year 4	11203	121.5
1749	—	2.2		419.6	178.2	—	—	Land, Labour Year 1, Capital Years 4 & 5	11210	85.8
2373	—	108.2		419.6	72.2	—	—	Land, Labour Years 1 & 2, Capital Year 4	11561	56.3
2707	—	133.5	46.9	419.6	—	—	—	Land, Labour Years 1 & 2, Capital Year 4	11709	44.2
2997	33.3	134.4	107.8	324.5	—	—	—	Land, Labour Years 1, 2 & 3	11805	33.1
		No further improvement in present value possible (unless labour and/or land resources increased)								

One could use Table 5 to obtain a guide as to how much one can afford to invest in one's own equipment (if it is to be used for pasture improvement only) and/or what the critical level of clearing costs is likely to be.

To examine the stability of the optimum situations when wool prices change the calculations were repeated at a net wool price of 4/- per lb. The relevant tables are given in the Appendix. At this lower price the present value of such investments (and the marginal products) is, of course, less, but combining remains the most profitable method under most situations. In fact, combining replaces the prepared seed bed method in the early section of the capital table (i.e. when capital is very scarce) as the increase of net income under the prepared seed bed method is reduced and slowed down by the lower wool price. The only other major change is that broadcasting with ground implements becomes more profitable than the aerial method when labour is very scarce.

Enough has been said to demonstrate that the most profitable method of improvement is often not the most intensive. It may be argued that this is something farmers discover in due course by themselves without any guidance. Even though the right methods are eventually discovered by trial and error, it seems desirable to reduce the need for such necessarily slow adaption by applied experimental work. Perhaps more serious is the consideration that the absence of this type of experiment means that research workers rarely face the problems in the form in which they confront the grazier. If the real limitations on the growth of output were more widely realised, the possibilities of making extensive techniques more effective (e.g. by soil pelleting of seed, sowing into pastures of different densities, etc.) would perhaps be examined more closely.

(iii) *The Optimum Area*

There remains one economic problem which the grazier must face—the timing of his improvement programme. Tables 3, 4 and 5 show not only the optimum methods to be used but also the optimum area to be improved in any one year, given the different factor combinations available. To some extent the farmer's problem here is simpler than the one posed in these tables. He will usually want to improve the whole area within one paddock, so that the range of possible choices is not infinite, as was assumed in the linear programme.[10]

However, our hypothetical example suggests that the numerical value of the limiting factors in a pasture improvement programme may not be readily apparent when such an investment is being planned. If money resources are limiting, it will usually be found that they are not limiting in the first or second years but only at a later stage in the development programme when additional investment in structural improvements and sheep numbers is needed to take full advantage of the additional feed produced. Even if a definite sum is laid aside at the outset of the investment—as has been assumed above—changing seasonal conditions

[10] It is possible to handle such discontinuities in linear programming by means of an algorithm recently devised by R. Gomory of Princeton University (c.f. *Econometrica*, Vol. 27, No. 2, April, 1959, p. 276).

Table 5

THE OPTIMUM PASTURE IMPROVEMENT PROGRAMME

(When the amount of labour available is varied and the wool price is 5/- a lb.)

Resources Required	*Aerial Year 1*	*Combining Year 1*	*Combining Year 2*	*Combining Year 3*	*Combining Year 4*	*Prepared Seed Bed Year 1*	*Limiting Resources*	*Present Value*	*Marginal Product Per Day*
Days	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*		£	£
6.6	116.9	152.9					Labour Year 1, Capital Year 4	4667	711.8
8.4	42.6	194.9	90.5				Labour Year 1, Capital Years 4 & 5	5950	711.6
8.8	—	205.1	97.4				Labour Years 1 & 10, Capital Year 5	6263	711.4
10.0	—	234.0	47.8	104.3			Labour Years 1 & 10, Capital Years 4 & 5	6974	573.7
11.6	—	271.3	—	48.7	127.6		Labour Years 1 & 10, Capital Years 4 & 5	7809	522.6
12.0	—	280.3	—	—	182.1		Labour Years 1 & 10, Capital Year 5	7993	479.1
12.4		268.6	—	—	206.7		Labour Years 4 & 10, Capital Year 5	8122	383.1
12.6		252.5	—	16.6	215.9		Labour Years 4 & 10, Capital Years 5 & 7	8205	330.8
13.3		99.5		115.2	235.3	52.4	Labour Years 4 & 10, Capital Years 5 & 7	8299	129.0
17.3		—	—	100.2	327.9	99.9	Labour Year 4, Capital Years 5, 6 & 7	8563	66.4
21.8		—	—	—	429.1	116.9	Capital Years 5 & 7	8820	57.9
			No further improvement in present value possible (unless capital is increased).						

and variations in stock prices can alter the optimum areas to be improved. In addition, many farmers will not be able to specify the exact amounts they are willing to invest at the outset. They will try to "feel their way" as they proceed. If seasons and prices are favourable they may be able and willing to increase their pasture improvement expenditure; on the other hand if their incomes decline they may be forced to curtail planned investment.

It must be admitted that in these circumstances the data available to us are far too limited to estimate the optimum timing of such an investment. For under these conditions we must try to balance the danger of attempting too much at first—involving some losses if purchases of fertilisers or sheep have to be cut down—against the danger of doing too little and not using the resources which we would have had available. Briefly the type of data one would require to determine the optimum programme under such conditions are: (a) the effect of varying stocking rates on improved pastures on wool and meat output and (b) the effect of varying fertiliser applications on the volume of feed produced during the early stages of an improvement programme. Furthermore it would be necessary to have some knowledge of the probability distribution of future incomes. It would then be possible to use a dynamic programming model to approximate the (ex post) optimum decisions at each stage of the improvement programme. In the absence of such information the farmer proceeds, as no doubt he must, by the use of a mixture of hunch and faith, with his job of trying to improve his country.

It may be argued that all these considerations are far too theoretical and have no possible practical significance. Recent empirical work on investment decisions in industry suggests that the area of uncertainty is usually so great that there is little room for the use of the investment criteria which have been discussed above. How much worse off is the farmer in the Australian wool industry where seasonal conditions and prices are so variable? The answer to this argument would seem to be that while we can never hope to get all the relevant data to enable a man to make absolutely correct decisions, half a loaf or even a quarter is better than no bread at all. While maximisation of incomes along the lines suggested above appears to be asking for the impossible, men constantly do and must adapt their economic behaviour in the light of changing circumstances and of the additional knowledge they gain. It is this process of adaptation which can be helped and made more rational by a more complete economic analysis.

Summary and Conclusion

An attempt has been made in this paper to consider the economic choices confronting the farmer who is considering the adoption of pasture improvement. These choices can be considered under two headings: (a) how profitable is such an investment? and (b) what is the optimum programme given the individual circumstances of each farmer?

While the information on profitability is subject to a great many qualifications, the typical long-run return on investment in pasture improvement in New South Wales is probably between 14% and 22%

(when costs and prices are at 1955/56 levels). The lag before receipts exceed costs—which will depend partly on the timing of the necessary capital investments—and the productivity of the improved pastures seem to be the most important determinants of profitability.

To obtain the best pasture improvement programme the farmer can vary fertiliser applications, the area to be improved each year, stock numbers and the cultural methods of improvement. Insufficient information is available to allow optimum methods of improvement to be worked out in most areas. This is partly because applied experimental work designed to yield quantitative relationships has, by and large, not been attempted. Available evidence suggests that average fertiliser applications are considerably below optimum levels at least in some areas of New South Wales.

It is shown that extension advice on the optimum cultural method is based on certain assumptions which will often be incorrect for an individual farmer. Linear programming is used to ascertain optimum programmes under differing conditions. It is shown that the limiting factors for many pasture improvement plans are likely to be the availability of money three to seven years after an improvement scheme is started. As the amount of money available in the relatively distant future is often pretty much of an unknown, it is doubtful whether such an optimum can be realised. In these circumstances it becomes important to know what are the likely costs of being wrong. If the farmer improves too small an area he will have funds available which it would have been profitable to invest in pasture improvements in earlier years. If the farmer attempts too much, he will have to economise on purchases of fertiliser and/or sheep. If information on the magnitude of such losses can be obtained, it may become possible to apply a dynamic programming model to this problem.

Appendix

Table 1

DETAILS OF LINEAR PROGRAMME ASSUMPTIONS

The linear programme matrix is based on the following considerations.

Activity	*Labour Requirements (Feb./March)*	*Money Requirements**
	Per 100 Acres of Improved Pasture	
Prepared Seed Bed		£
Plough (November. Plough cut 2′ 6″. Speed 3½ miles an hour—1.06 acres an hour or 11.8 days [of 8 hours each] for 100 acres).	—	25.96
2 Discings—6′ 6″ width at 3½ miles an hour = 22.1 acres a day or 4.5 days for 100 acres (each discing).	9.04	19.91
Sowing—8′ at 4 miles an hour = 31.0 acres a day or 3.2 days for 100 acres.	3.22	7.08
Total of above	12.26	52.95
Combining 8′ cut; speed 3 m.p.h.—23.3 acres per day.	4.29	9.44
Broadcasting 50 acres per day.	2.0	4.2
Aerial No labour required (net contract cost = £3.4 per ton).	—	17.0
Fertiliser 1 cwt. of superphosphate per acre annually for 10 years and ½ cwt. annually afterwards. £14/16/- per ton on farm—except for aerial, where bulk rates have been used (£13/11/-).	— (Does not have to be spread at same time as sowing of new pasture.)	74.0

* Tractor costs 5/6 an hour (running costs only).

Sheep Purchases—at a wool price of 5/- a lb.

Gross cost £4 minus net return from 9 lbs. of wool at 5/- a lb. = £2/5/- plus 10/- costs of shearing, marketing and freight = net cost £2/5/- a head.

At a wool price of 4/- a lb.: Gross cost £3/4/- minus net return from wool £1/16/- plus 10/- costs of shearing, etc. = net costs £1/18/- a head.

Table 2

INCREASED SHEEP NUMBERS ON 100 ACRES

Year	*Prepared Seed Bed*	*Combining*	*Broadcasting*	*Aerial*
1	0	0	0	0
2	60	30	20	20
3	180	70	40	40
4	220	100	80	90
5	230	140	120	130
6	240	180	140	150
7	240	200	160	170

Extra wool production per acre, in all years except Year 1, is equal to 2 lb. per acre (from sheep previously run on native pasture). On prepared seed bed 4 lb. of wool is lost in Year 1 due to inability to graze new pasture fully in that year.

Fencing

£1 per extra sheep carried required in 4th year—except for prepared seed bed, where 60% of the expenditure is required in 1st year to fence off newly sown areas.

The 5/- and 4/- matrices used are given below. This is followed by the optimum programmes based on the 4/- matrix.

Labour requirements for sheep in subsequent years based on .13 days during February/March per 10 extra sheep. This includes allowances for drenching, crutching, moving sheep, etc.

Table 3

RESOURCE REQUIREMENTS FOR DIFFERENT PASTURE IMPROVEMENT METHODS

(Wool price 5/- a lb.)

	Prepared Seed Bed Year 1	Year 2	Year 3	Year 4	*Combining* Year 1	Year 2	Year 3	Year 4	*Broadcasting* Year 1	Year 2	Year 3	Year 4	*Aerial* Year 1	Year 2	Year 3	Year 4	*Unit*
Land	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100 acres
Money																	
Year 1	4.27				.33				.28				.41				£100
„ 2	5.9	4.27			1.29	.33			1.01	.28			1.27	.41			£100
„ 3	7.83	5.9	4.27		1.95	1.29	.33		1.39	1.01	.28		1.78	1.27	.41		£100
„ 4	7.16	7.83	5.9	4.27	3.3	1.95	1.29	.33	3.37	1.39	1.01	.28	4.24	1.78	1.27	.41	£100
„ 5	3.82	7.16	7.83	5.9	2.73	3.3	1.95	1.29	3.15	3.37	1.39	1.01	3.98	4.24	1.78	1.27	£100
„ 6	.3	3.82	7.16	7.83	1.46	2.73	3.3	1.95	1.78	3.15	3.37	1.39	2.55	3.98	4.24	1.78	£100
„ 7	−3.56	.3	3.82	7.16	.96	1.46	2.73	3.3	.06	1.78	3.15	3.37	.78	2.55	3.98	4.24	£100
Labour																	
Year 1	12.26				4.29				2.0								Days
„ 2	.78	12.26			.39	4.29			.26	2.0			.26				„
„ 3	2.34	.78	12.26		.91	.39	4.29		.52	.26	2.0		.52	.26			„
„ 4	2.86	2.34	.78	12.26	1.3	.91	.39	4.29	1.04	.52	.26	2.0	1.17	.52	.26		„
„ 7	3.12	3.12	2.99	2.86	2.6	2.34	1.82	1.3	2.08	1.82	1.56	1.04	2.21	1.95	1.69	1.17	„
„ 8	3.12	3.12	3.12	2.99	2.6	2.6	2.34	1.82	2.08	2.08	1.82	1.56	2.21	2.21	1.95	1.69	„
„ 9	3.12	3.12	3.12	3.12	2.6	2.6	2.6	2.34	2.08	2.08	2.08	1.82	2.21	2.21	2.21	1.95	„
„ 10	3.12	3.12	3.12	3.12	2.6	2.6	2.6	2.6	2.08	2.08	2.08	2.08	2.21	2.21	2.21	2.21	„
Maximising Values	£ 2285	2073	1878	1705	1921	1742	1578	1433	1173	1063	963	862	1481	1343	1219	1108	£ per 100 acres

Table 4

RESOURCE REQUIREMENTS FOR DIFFERENT PASTURE IMPROVEMENT METHODS

(Wool price 4/- a lb.)

	Prepared Seed Bed				*Combining*				*Broadcasting*				*Aerial*				*Unit*
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	
Land	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100 acres
Money Year 1	4.07				.43				.38				.51				£100
„ 2	5.59	4.07			1.38	.43			1.14	.38			1.4	.51			£100
„ 3	7.47	5.59	4.07		2.13	1.38	.43		1.64	1.14	.38		2.03	1.4	.51		£100
„ 4	7.57	7.47	5.59	4.07	3.79	2.13	1.38	.43	3.76	1.64	1.14	.38	4.59	2.03	1.4	.51	£100
„ 5	5.28	7.57	7.47	5.59	3.63	3.79	2.13	1.38	3.86	3.76	1.64	1.14	4.69	4.59	2.03	1.4	£100
„ 6	2.86	5.28	7.57	7.47	2.95	3.63	3.79	2.13	3.44	3.86	3.76	1.64	4.27	4.69	4.59	2.03	£100
„ 7	.25	2.86	5.28	7.57	1.38	2.95	3.63	3.79	2.12	3.44	3.86	3.76	3.33	4.27	4.69	4.59	£100
Labour Year 1	12.26				4.29				2.0								Days
„ 2	.78	12.26			.39	4.29			.26	2.0			.26				„
„ 3	2.34	.78	12.26		.91	.39	4.29		.52	.26	2.0		.52	.26			„
„ 4	2.86	2.34	.78	12.26	1.3	.91	.39	4.29	1.04	.52	.26	2.0	1.17	.52	.26		„
„ 7	3.12	3.12	2.99	2.86	2.6	2.34	1.82	1.3	2.08	1.82	1.56	1.04	2.21	1.95	1.69	1.17	„
„ 8	3.12	3.12	3.12	2.99	2.6	2.6	2.34	1.82	2.08	2.08	1.82	1.56	2.21	2.21	1.95	1.69	„ „
„ 9	3.12	3.12	3.12	3.12	2.6	2.6	2.6	2.34	2.08	2.08	2.08	1.82	2.21	2.21	2.21	1.95	„
„ 10	3.12	3.12	3.12	3.12	2.6	2.6	2.6	2.6	2.08	2.08	2.08	2.08	2.21	2.21	2.21	2.21	
Maximising Values	£ 1347	1220	1106	1003	1218	1105	1001	908.3	1035	938.1	849.5	770.8	973.6	882.4	798.9	724.8	£ per 100 acres

Table 5

THE OPTIMUM PASTURE IMPROVEMENT PROGRAMME

(When the area of land is varied and the price of wool is 4/- a lb.)

Resources Required Acres	*Prepared Seed Bed Year 1*	*Combining Year 1*	*Combining Year 2*	*Combining Year 3*	*Combining Year 4*	*Broadcasting Year 4*	*Limiting Resources*	*Present Value £*	*Marginal Product Per Acre*
132.1	132.1						Capital Year 4	1779	13.5
263.9	—	263.9					Capital Year 4	3214	10.9
274.4	—	250.3	24.1				Capital Years 4 & 5	3315	9.6
297.4	—	244.8	—	52.2			Capital Years 4 & 5	3505	8.4
302.5	—	258.9	—	—	43.6		Capital Year 5	3550	8.2
390.6	—	204.9			185.7		Capital Years 5 & 6	4182	7.18
392.6	4.6	195.6			192.3		Capital Years 5, 6 & 7	4192	4.8
393.9	—	204.3			176.5	13.0	Capital Years 5, 6 & 7	4192	.2
			No further increase in present value possible.						

Table 6

THE OPTIMUM PASTURE IMPROVEMENT PROGRAMME

(When the amount of money available is varied and the wool price is 4/- a lb.)

Resources Required £	*Prepared Seed Bed Year 1*	*Prepared Seed Bed Year 2*	*Prepared Seed Bed Year 3*	*Com-bining Year 1*	*Com-bining Year 2*	*Com-bining Year 3*	*Com-bining Year 4*	*Broad-casting Year 4*	*Limiting Resources*	*Present Value* £	*Marginal Product Per £100 Capital*
1523				311.2			268.9	19.9	Capital Years 5, 6 & 7 & Land	6386	419.2
1528	7.1			299.0			293.9	—	Capital Years 5, 6 & 7 & Land	6407	419.0
1536	—			314.7			285.3	—	Capital Years 5 & 6 & Land	6424	227.7
1772	—			419.6			180.4	—	Capital Year 5, Labour Year 1 & Land	6749	137.6
1896	—			419.6		164.8	15.6	—	Capital Years 5 & 6, Labour 1 & Land	6902	123.6
1920	—			419.6	7.8	172.6	—	—	Capital Years 5 & 6, Labour 1 & Land	6925	91.6
2207	—			419.6	180.4	—	—	—	Capital Year 5, Labour 1 & Land	7104	62.7
2616	—	108.2		419.6	72.2	—	—	—	Land, Labour Years 1 & 2, Capital Year 5	7229	30.4
2884	—	133.5	46.9	419.6	—	—	—	—	Land, Labour Years 1 & 2	7259	11.2
				No further increase in present value possible.							

Table 7

THE OPTIMUM PASTURE IMPROVEMENT PROGRAMME

(When the amount of labour available is varied and the wool price is 4/- a lb.)

Resources Required Days	*Broad-casting Year 1* Acres	*Broad-casting Year 3* Acres	*Broad-casting Year 4* Acres	*Combining Year 1* Acres	*Combining Year 3* Acres	*Combining Year 4* Acres	*Limiting Resources*	*Present Value* £	*Marginal Product* £
5.39	259.1						Capital Year 5	2681	497.6
5.45	249.6			9.9			Capital Year 5 and Labour Year 1	2704	388.0
6.6	161.7	57.0		77.8			Capital Years 5 & 6, Labour Years 1 & 10	3105	356.9
9.2	—	36.4	138.7	215.5			Capital Years 5 & 6, Labour Years 1 & 10	4003	335.8
9.4	—	31.4	155.8	212.4			Capital Years 5, 6 & 7, Labour Year 10	4054	301.1
9.5	—	—	186.3	217.0			Capital Years 5 & 7, Labour Year 10	4079	242.5
10.1	—	—	29.8	205.5		159.5	Capital Years 5 & 7, Labour Years 4 & 10	4181	172.6
10.12	—	—	24.5	204.3	3.0	162.3	Capital Years 5, 6 & 7, Labour Years 9 & 10	4181	56.4
10.5	—	—	13.1	204.3	—	176.5	Capital Years 5, 6 & 7	4192	28.2
			No further increase in present value possible.						

Table 8

OPTIMUM PASTURE IMPROVEMENT PROGRAMMES IF SHEEP NUMBERS ARE MAXIMISED IN DIFFERENT YEARS

(Wool price = 5/- a lb.)*

	Year 2	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 10*
Optimum Programme for Year / *Year*	Combining, Year 1—303.0 acres	Prepared Seed Bed, Year 1—113.7 acres; Combining, Year 1—56.4 acres	Prepared Seed Bed, Year 1—83.4 acres; Combining, Year 2—206.4 acres	Combining, Year 1—226.5 acres; Combining, Year 3—195.7 acres	Combining, Year 1—286.0 acres; Combining, Year 4—169.8 acres	Combining, Year 1—252.9 acres; Broadcasting, Year 3—130.9 acres; Combining, Year 4—80.4 acres; Broadcasting, Year 4—23.6 acres	Prepared Seed Bed, Year 1—114.1 acres; Combining, Year 3—46.7 acres; Combining, Year 4—298.8 acres; Broadcasting, Year 4—86.9 acres.
	EXTRA SHEEP WHICH CAN BE CARRIED EACH YEAR						
2	91	85	50	68	86	76	68
3	212	244	212	159	200	177	205
4	303	307	328	285	286	279	265
5	424	340	398	454	451	435	402
6	545	374	489	604	634	626	564
7	606	386	572	727	742	762	708
8	606	386	613	805	810	830	880
9	606	386	613	844	878	893	1027
10	606	386	613	844	912	914	1104

* Restrictions used: Land 600 acres
Labour 18 days
Money £1000