FINANCIAL RETURNS AND CAPITAL REQUIREMENTS FOR OPTIMUM PASTURE IMPROVEMENT PLANS

ROBERT A. PEARSE*

1. INTRODUCTION AND PROBLEM SPECIFICATION

Since World War II there has been a rapid increase in the area sown to improved pastures in Australia generally and New South Wales in particular. Despite this increase there has been much speculation as to the reasons why even more country has not been improved, especially as spectacular increases in carrying capacity result. There have been a number of studies of economic aspects of pasture improvement stimulated by these observations. This study is intended to extend or supplement them, because much of the previous work has been somewhat limited.

The objects of this paper are to:—

(1) Outline the basic asumptions on which the whole study is based.

(2) Determine, where finance is provided from savings supplemented by reinvestment of all profits (when necessary) due to the improvement programme:—

(a) Whether the level of capital availability affects:—

(i) The total capital required to get the property wholly under improved pasture.

(ii) The rate of return on the money invested.

(iii) The time before the programme becomes self financing.

(iv) The years when capital is most limiting.

(b) The optimum method or methods of sowing pasture, and whether sowing should be yearly or at irregular intervals.

* Lecturer in Farm Management, Faculty of Agricultural Economics, University of New England. The author wishes to acknowledge the many helpful comments and criticisms on a draft of this paper by members of the Faculty. Grateful acknowledgement is made to the Economic and Financial Research Fund, Reserve Bank of Australia whose generous financial assistance was used to meet computational expenses.

(*c*) Whether plans prove stable over wide changes in capital availability or if small changes considerably alter the optimum sowing combinations.

(*d*) Whether a change in wool prices causes a change in the optimum combination of sowing methods, or alters the sequence of their introduction.

(*e*) The relationships between the marginal value products of the limiting resources, where the price of wool is assumed to be stable for 20 years at either 5s. 0d. or 4s. 0d. per lb.

A brief summary of the major studies on the economics of pasture improvement in New South Wales follows. The first of these, a budget for a hypothetical wheat-sheep farm in southern New South Wales drawn up by Gruen,[1] suggested that pasture improvement would increase net income by 80-100 per cent at 1955-56 prices. However, subsidiary budgets showing anticipated year by year effects indicated that a farmer could "expect to be financially worse off for six to ten years than he would be otherwise". These results were not discounted, which would give an advantage to pasture improvement where it takes time for the benefits to be realized, and Gruen concluded that pasture improvement was worthwhile.

To assess the likely financial results following aerial seeding of a hypothetical Northern Tablelands property at various wool prices and for two labour situations, Gruen and Pearse[2] used parametric budgeting. Their results showed discounted returns to capital over a forty-year period of from 6.2 per cent to 31.8 per cent as wool prices were varied from 3s. 0d. to 8s. 0d. per lb. where no extra permanent labour was required and from zero to 27.5 per cent with permanent extra labour.

A case study approach was used by Campbell and Shand[3] to study six grazing properties in the Central and Southern Tablelands and one North Coast dairy farm. They appear to use the net income from pasture improvement in the final year of their study over all the capital invested in pasture improvement to that date to give the rate of return.[4] The inherent variability of the agricultural environment makes one suspect that this approach could be quite misleading. For example one of the properties is assessed to show a return of 60 per cent. The net income had increased in the final year to £3,524 from £803 in the previous year. This was a far greater change than the average for the properties studied.

These and other studies were summarized by Gruen[5] who applied the discounting technique to all results. He concluded that reasonable estimates of the long term profitability of pasture improvement lay between 14 and

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[1] F. H. Gruen, "Financial Aspects of Pasture Improvement on Southern Wheat-sheep Farms", this *Review*, Vol. 24, No. 4 (December, 1956).

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

[3] Keith O. Campbell and Richard T. Shand, "An Economic Study of Pasture Improvement on Some Farms in New South Wales", Department of Agricultural Economics, University of Sydney, mimeo, Report No. 2 (1959).

[4] *Ibid.*, p. 54, 65.

[5] F. H. Gruen, "Pasture Improvement—The Farmers Economic Choice", *Australian Journal of Agricultural Economics*, Vol. 3, No. 2 (December, 1959).

22 per cent. This paper was concluded with a linear programming study designed to give the optimum sowing plan for certain situations. Partly due to the lack of a suitable programming routine this work was of limited value.

Finally Throsby,[6] in an example which aroused some controversy,[7] used a pasture improvement problem to illustrate the problems of introducing time into a linear programming study. In so far as this is of methodological rather than direct interest we need not consider it further here.

The cycle of publications ranges from theoretical exercises in likely profitability to case studies of actual farms. These early studies had the deficiency that discounting was not considered and that they only examined a given model. No comment was made on the likelihood of whether or not a better model could have been formulated.

Gruen and Pearse appreciated from their study of aerial seeding[8] that there could well be an economic problem in deciding between ground and aerial sowing of a pasture. Following this line of work Gruen published his linear programming study.[9] As mentioned previously, this work has a number of limitations, for example:—

(1) Labour was considered to be the main limiting factor in relation to the yearly acreage sown. The high marginal returns of from £712 to £58 per day seem highly unrealistic as Gruen mentions in a footnote.[10] Many factors may limit the acreage to be sown in a year—labour, power and amount of machinery available, fear of the effect of drought if too much of the property is ploughed up, aversion to borrowing to finance some or all of the programme, the desire to breed to maintain stock quality, and fear of purchasing stock and introducing disease are a few of the many factors. Thus Gruen's marginal product for labour may have been measuring many of these other restraints.

(2) The use of a lump sum of capital. Gruen argued that a grazier may wish to know how much he would need to spend and set himself some limit. Even so, this could be a yearly limit and would seem to be no reason for ignoring the possibility of savings over the period considered. Gruen's situation could only be that of a grazier who opened an account into or from which all receipts and expenses of the pasture improvement programme were paid. It would either have had an initial capital sum—which could not be increased by later earinngs—or would have had a specific overdraft limit which could not be changed. Neither of these pictures seem to approach reality closely.

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[6] C. D. Throsby, "Some Notes on 'Dynamic' Linear Programming", this *Review*, Vol. 30, No. 2 (June, 1962).

[7] "Some Notes on 'Dynamic' Linear Programming", this *Review*, Vol. 30, No. 4 (December, 1962), pp. 228-232, and "Some Notes on 'Dynamic' Linear Programming", this *Review*, Vol. 31, No. 1 (March, 1963), pp. 40-41.

[8] Gruen and Pearse, *op. cit.*

[9] Gruen, 1959, *op. cit.*

[10] *Ibid.*, p. 31.

(3) It is difficult to calculate precisely how the cost coefficients were obtained using the data provided. Some appear low in comparison with figures in the present study, e.g., for prepared seed bed £7.8 compared with £15.2 per acre.

(4) The period of planning was only four years. Such a short span will lay emphasis on the less labour intensive methods—with labour limiting. In the long run a sixth year sowing using much labour may be preferable to a fourth year sowing using little labour.

(5) Other methods of sowing need to be considered. It is fair to say that some of Gruen's restraints of both time and sowing methods may have been due to limited computer capacity. This is not to say that they may not place serious limitations on the results.

(6) Finally, no special consideration was made of the problems of income tax, which is very difficult to take into effect, and of clearing costs, which frequently must be incurred before a ground sowing can take place.

The above deficiencies are adequate testimony of the need to extend the study of the economics of pasture improvement to a more detailed level, including a longer time period, a comparison of the use of various types of loans with savings, to consider clearing costs and to make some tentative estimate of the effect of income tax.

2. THE METHODS OF ESTABLISHING AN IMPROVED PASTURE

There are two ways of introducing new pasture species, either by sowing the seed into the soil or by dropping it on the ground surface.

Five variates of these methods were considered for establishing optimum plans for pasture improvement. They were:—

(i) Prepared Seed Bed.
(ii) Combining.
(iii) Combining, Later Ripped up and Resown.
(iv) Broadcasting.
(v) Aerial Seeding and Topdressing.

What is meant by each of these methods is outlined below. An appropriate abbreviation is indicated in each case.

(i) *Prepared Seed Bed* (PSB). This means the sowing of a grass-clover seed mixture on a carefully prepared fallowed seed bed. As such it would offer the most favourable conditions for pasture establishment, especially as little or no stocking was assumed for some months.

(ii) *Combining* (COM). This means the introduction of seed into the ground by means of a combine, disc drill or sod seeder. Compared with prepared seed bed it requires lower labour and machinery costs and no reduction of grazing. However, due to competition with existing species, its performance would be below that of the prepared seed bed.

(iii) *Combining, Later Ripped up and Resown* (RC). Waring[11] suggested that this was a possibility worth examining as he had seen it used successfully on the North Coast. It was included as a theoretical possibility but in the course of extension talks it has been found that some Tablelands graziers successfully use such a technique. It consists of sowing clover (and spreading fertilizer) by combine, drill or sod seeder. After allowing fertility to build up for 4, 5, 6 or 7 years it would be ploughed up and sown to a grass mixture. The advantage of this method is lower establishment cost, the subsequent heavy expense of ploughing and sowing grasses being partly compensated by the increased stock carried.

(iv) *Broadcasting.* This means the broadcasting of seed from an implement moving on the ground. Preliminary studies showed it was unlikely to enter the solution, so it was excluded from the final study.

(v) *Aerial Seeding and Topdressing* (ATD). The spreading of seed and fertilizer from an aeroplane has the advantage of low labour requirement, avoidance of purchasing expensive cultivation machinery, and speed and convenience of operation. It has the disadvantage that the seed is not covered with the consequent likelihood of very poor establishment compared with the other methods. It was considered that this was the roughest and cheapest way in which a farmer could improve. It was assumed that few farmers would spread fertilizer without adding clover seed.

One other possible establishment method which is of importance on some properties is the use of a cover crop, a technique which was not included in the study owing to lack of data.

3. SELECTION OF THE COEFFICIENTS

In this section the source or method of estimating the coefficients such as yearly cash flows or carrying capacity is discussed. Some comments about the reliability of the data are made.

Carrying Capacity of the Improved Pastures

This will be affected by method of establishment, fertilizer history, stock management, seasonal conditions, soil type, and so on. Therefore any estimate made must be approximate.

In so far as possible the aim of this study was to use the results of graziers who had employed one or other of the techniques considered. The estimates are averages over a range of seasons, soil types and stock managements from a reasonably homogeneous geographical area. In this way some of the biasses inherent in the case study method of obtaining co-

[11] E. J. Waring, Senior Lecturer in Farm Management, University of New England.

efficients are avoided. However graziers in fact may underestimate pasture performance by understocking. Understocking may be due to factors such as inexperience of the real potential of new pastures and in managing improved pastures, to lack of capital and to the desire to breed rather than to buy or the unavailability of quality stock for purchase. It was not possible to assess the extent of these limitations.

The estimated increases in carrying capacity over the stocking rate of native pasture are shown in Table I. Note that a year ends on June 30. Because pastures are usually sown in February to April it was stipulated that no benefit would be obtained in the "year" of sowing. Extra stock were purchased off shears so no income is obtained from them until the third year, although this may have been only eighteen calendar months.

TABLE I

Budget Showing Assumed Sheep Purchases and Carrying Capacities Per 100 *Acres Sown*

Year	PSB		COM		ATD		$RC1_5$		$RC1_8$	
	Sheep Purchased	Total Extra Sheep	Sheep Purchased	Total Extra Sheep	Sheep Purchased	Total Extra Sheep	Sheep Purchased	Total Extra Sheep	Sheep Purchased	Total Extra Sheep
1	..	..	..	..	..	..	..	..	..	..
2	60	60	30	30	20	20	30	30	30	30
3	120	180	40	70	20	40	40	70	40	70
4	40	220	30	100	50	90	30	100	30	100
5	10	230	40	140	40	130	..	100	40	140
6	10	240	40	180	20	150	40	140	40	180
7	..	240	20	200	20	170	40	180	20	200
8	..	240	..	200	..	170	40	220	..	200
9	..	240	..	200	..	170	20	240	20	220
10	..	240	..	200	30	200	..	240	20	240

In referring to the year and method of sowing the abbreviated title followed by a figure is used. Thus PSB 1 is prepared seed bed sown in the first year of the development programme and COM 3 is combining alone in the third year of the programme. In the case of RC two sets of figures, one being a subscript, are used. Thus $RC1_5$ would mean the area was combined in year 1 and ripped up and resown in year 5 of the programme, whilst RC 3_{10} would denote a first sowing in year 3 and resowing in year 10.

The estimates for PSB are based on a survey of 24 farms.[12] The estimates for ATD were based on a survey carried out in 1958[13] when this technique was in its infancy and a few graziers believed that ATD would equal PSB in performance in six years. This was originally discounted as being due to superior management, but recent discussion with graziers who have had the benefit of a further five years' experience with the technique suggests the estimates were correct. Recent work which will be published later has been revised by making ATD and PSB equal in the sixth year. This has the effect of practically making the RC technique redundant.

[12] Gruen and Pearse, *op. cit.*, p. 128.

[13] Gruen and Pearse, *loc. cit.*, and p. 119.

The estimates for COM were supplied by Roe[14] based on his research work at the C.S.I.R.O. Research Station, "Chiswick", located between Armidale and Uralla. As the final carrying of COM was below PSB, the estimates for RC were increased after resowing to equal that of PSB.

Capital Requirements

The expenses of a pasture improvement programme may be thought of as:—

(i) The cost of establishing a pasture, i.e., seed, fertilizer, fuel, oil, and possibly loss of production if a portion of the property is not available for grazing for some months. Labour has not been included. For a 1,000-acre unimproved property one man would provide more than enough labour and so it is a fixed cost. In this region it is common to find a ratio of one man to 2,500 dry sheep. Hence the need for extra labour has not been considered, although casual labour would be needed once the maximum carrying capacity had been attained. By this stage, as we shall see later, there would be adequate money available.

(ii) The cost of obtaining extra stock to use the pasture—either the direct cash expense of purchase or the indirect loss of receipts by selling fewer stock if one breeds up.

(iii) The cost of fencing, water supplies, stock yards, extra buildings, etc., needed to run the extra stock.

(iv) The cost of maintaining the pasture and running the extra stock, and finally

(v) Interest payments if money is borrowed.

In this study there has been no difference made between capital and maintenance charges, that is, both expenditures have been paid from a common fund, composed of savings and profit from the pasture improvement programme. If one considered the effects of loans from stock firms for sheep purchase it would be necessary to have two funds. The capacity of "Silliac" prevented this being done, but present work, including this requirement, is being undertaken with the Weapons Research Establishment Computer at Salisbury.

General Assumptions

(a) Expenditure Required for Pasture Improvement

This section covers the assumptions common to all methods of establishment. The extra stock are wethers, kept for four years, subject to a 2 per cent death loss annually and a 10 per cent culling in the first year, these losses being replaced annually. Running expenses are 10s. 0d. per head, which is comparable with James' findings.[15] They cost £4 with wool at 5s. 0d. per lb. and £3 with wool at 4s. 0d. per lb. Cast-for-age (c.f.a.) sheep were sold as fats for £2 per head. This gives an annual depreciation

[14] Then Principal Research Officer, Division of Plant Industry, C.S.I.R.O., Armidale. At present, Division of Tropical Pastures, The Cunningham Laboratory, St. Lucia, Queensland.

[15] B. J. F. James, "Report on an Economic Survey of New England Grazing Properties", this Review, Vol. 29, No. 4 (December, 1961), Table 14, p. 174.

of 10s. 0d. or 5s. 0d., which is greater than that experienced by graziers who can buy 5,000 head annually. However, graziers who purchase smaller numbers seem to experience higher costs than the large graziers's total depreciation of about 15s. 0d. per head.

Capital expenditure on fences, buildings, water supplies, yards, etc., required for the extra stock was estimated to be 25s. 0d. per head.[16] These were depreciated at 2½ per cent, which was charged as a cash cost. Expenditure on establishing a pasture, that is, the variable costs[17] such as fuel, seed, fertilizer, repairs and contract charges (if any), was capitalized. Fertilizer costs were capitalized for the first two years, the costs being assessed at £14.8 per ton bagged and £13.4 for bulk superphosphate, plus £8 per 100 acres for ground spreading and £4.2 per ton for aerial spreading. The application was at one cwt. per acre[18] for nine years and subsequently at a half cwt.

(b) Income Returned by the Improved Pastures

The returns from pasture improvement have three main sources:—

(1) More wool from existing sheep due to better nutrition.

(2) Wool from the extra sheep carried.

(3) Sale of extra culls and c.f.a.

Income from sources such as lower death losses, less drenching, better prices for fats—and possibly tax free capital gains from the sale of the property—are not included in the study. The increases in wool cut are based on survey results;[19] for existing sheep, they are 1 lb. per head in the second year, with a further 1 lb. per head in subsequent years. The extra sheep were considered to cut 9 lb. up to the ninth year and 10 lb. per head thereafter. These yields may be a little conservative for properties with above average management.

SPECIAL ASSUMPTIONS

The particular asumptions about seed costs, timing of capital expenses, etc., for each method are outlined below. The detailed estimates of the receipts and expenditures are shown in Tables 2, 3, 4, 5, and 6 for each of the sowing methods, based on a sowing unit of 100 acres.

The headings should be explanatory except for:—

(1) "Amount allowable for tax deduction". This is the amount which could be claimed as a tax deduction in the year, including special depreciation allowance of 20 per cent.

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[16] Gruen and Pearse, *op. cit.*, p. 115.

[17] It was assumed that necessary machinery was available. If it were not it is expected that ATD would have been a more dominant technique than it was found to be. Linear Programming does not readily lend itself to the analysis of high fixed costs before one technique can be introduced.

[18] In recent years many graziers have used 2 cwt. per acre for the first year or two. Waring and Sturgess (Private Communication) have evidence suggesting that one cwt. is adequate (except perhaps on basalt soils) as there are usually insufficient stock to utilize the extra growth produced by the second cwt. of fertilizer.

[19] Gruen and Pearse, *op. cit.*, pp. 120-121.

(2) "Tax at 5s. 0d. in the £" and "tax at 10s. 0d. in the £". These show net annual cost less the amount by which the cost would be "reduced" if income tax were 5s. 0d. or 10s. 0d. in the pound respectively. For instance by reducing one's taxable income from £2,000 to £1,000 one saves £270 which is equivalent to reducing tax by 5.4s. in the pound. That is, of £1,000 spent on fertilizer £730 would come from the grazier and £270 from tax saving. Reducing taxable income from £5,000 to £4,000 saves £505 tax or about 10s. in the pound.

(3) "Cumulative Cost + 6% Interest". This is the amount which is used as the capital requirement in a given year. It is the sum of the net annual cost plus interest in the given year and the cumulative cost plus interest for the previous year, except that once a figure becomes negative interest is no longer calculated on it. It is intended to represent the balance in a bank account which had all the receipts and payments of the development programme charged to it and which bears an overdraft rate of 6 per cent.

(*a*) *Prepared Seed Bed* (See Table 2)

The special expenses in the first year consisted of £200 for seed, £150 for fencing and water, £96 for cultivation and sowing, seed and fertilizer, and £74 for fertilizer per 100 acres. Cultivation costs exclude the fixed costs of machinery as it was assumed available. Frequently a large paddock must be subdivided when sown to PSB so considerable provision was made for fencing and water costs.

The second year expenditure is for fertilizer and the fourth year expenditure is to bring the total outlay to 25s. per head and may be for extensions to yards or buildings.

(*b*) *Combining* (See Table 3)

The special expenses in the first year consisted of £150 for seed, £74 for fertilizer and £17 for machinery per 100 acres. The second year expenditure is for fertilizer. It was assumed that there was no subdivision fencing or expenditure on water supplies until the third year (£150) due to the slow increase in stock numbers. A further £50 was set aside in years eight and ten for such things as yards and shed extensions.

(*c*) *Aerial Sown and Topdressed* (See Table 4)

The special expenses in the first year consisted of £80 for seed (white clover only), £67 for superphosphate, £21 for spreading, and £20 for airstrip construction per 100 acres. The latter expense is most variable in practice and is often only a few pounds. These charges may be high as frequently expenditure on seed is only £20. However it is also common to use 2 cwt. of fertilizer which would give about the same total cost. As extra stock need to be present to give the full benefits of fertilizer and this is not common with ATD it is likely that in practice the costs and returns are comparable with those assumed here.

Expenditure in later years is for fertilizer, in the second year, fences, yards, water supplies, and buildings in the third and eighth years as the stock numbers increase and following the initial clover sowing £50 for spreading grass seed in the fifth and sixth years.

TABLE 2

*Budget of Anticipated Costs and Returns per 100 Acres—Prepared Seed Bed**

Wool Price 5s. per lb.

Year	Capital Expenditure			Running Costs			Income				Gross Expenditure		Net Annual Cost			Cumulative Cost + 6% Interest		
	Sheep Purchased	Seed Fertilizer Cultivation Improvements	Total	Fertilizer and Spreading Costs	Dip, Drench, Shearing, Deaths, Replacements	Total	From Existing Sheep	From Extra Sheep	Gross	Net	Total Annual Cost	Amount Allowable for Taxable Deduction	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £
1	..	520	520	..	5	5	..	..	..	— 5	525	400	525	425	325	557	451	344
2	240	82	322	..	39	39	25	..	25	—14	361	176	336	292	248	946	787	628
3	480	..	480	82	131	213	50	156	206	— 7	693	303	487	411	336	1,520	1,270	1,022
4	160	..	160	82	203	285	50	462	512	227	445	349	— 67	—154	—241	1,540	1,183	828
5	40	150	190	82	232	314	50	561	611	297	504	388	—107	—204	—301	1,519	1,038	559
6	40	..	40	82	425	507	50	671	721	214	547	373	—174	—267	—360	1,426	817	211
7	..	..	..	82	451	533	50	709	759	226	533	359	—226	—316	—406	1,272	531	—195
8	..	..	..	82	445	527	50	709	759	232	527	386	—232	—328	—425	1,102	215	— 620
9	..	..	..	82	321	403	50	688	738	355	403	364	—335	—426	—517	813	—211	—1,137
10	..	..	..	82	441	523	75	762	837	314	523	338	—314	—398	—483	529	—669	—1,620
11	..	..	..	45	421	466	75	751	826	360	466	299	—360	—435	—510	179	—1,044	—2,130
12	..	..	..	45	413	458	75	749	824	366	458	302	—366	—441	—516	—187	—1,485	—2,646
											Wool Price 4s. per lb.							
1	..	520	520	..	5	5	..	..	..	— 5	525	400	525	425	325	557	451	344
2	180	82	262	..	38	38	20	..	20	—18	300	130	280	248	215	887	741	593
3	360	..	360	82	122	204	40	125	165	—39	564	256	399	335	271	1,363	1,140	916
4	120	..	120	82	181	263	40	370	410	147	383	289	—27	— 99	—171	1,416	1,103	790
5	30	150	180	82	205	287	40	450	490	203	467	337	— 23	—107	—191	1,477	1,056	635
6	30	..	30	82	351	433	40	569	609	176	463	308	—146	—223	—300	1,411	883	355
7	..	..	..	82	372	454	40	594	634	180	454	289	—180	—252	—324	1,305	663	33
8	..	..	..	82	366	448	40	591	631	183	448	305	—183	—259	—335	1,190	428	—302
9	..	..	..	82	273	355	40	528	568	213	355	303	—213	—289	—365	1,036	147	—667
10	..	..	..	82	353	435	60	633	693	258	435	275	—258	—327	—396	825	—180	—1,063
11	..	..	..	45	348	393	60	621	681	288	393	238	—288	—347	—407	569	—527	—1,470
12	..	..	..	45	342	387	60	621	681	294	387	237	—294	—353	—412	291	—880	—1,882
Column	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

* Assumptions—see text.

TABLE 3

*Budget of Anticipated Costs and Returns per 100 Acres Combined**

Wool Price 5s. per lb.

Year	Capital Expenditure			Running Costs			Income				Gross Expenditure		Net Annual Cost			Cumulative Cost + 6% Interest		
	Sheep Purchased	Seed Fertilizer Cultivation Improvements	Total	Fertilizer and Spreading Costs	Dip, Drench, Shearing, Deaths, Replacements	Total	From Existing Sheep	From Extra Sheep	Gross	Net	Total Annual Cost	Amount Allowable for Taxable Deduction	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £
1	..	241	241	..	..	..	..	..	..	..	241	241	241	181	121	255	192	128
2	120	82	202	..	15	15	25	..	25	10	217	112	192	164	136	474	377	280
3	160	..	160	82	51	133	50	78	128	— 5	293	156	165	126	87	677	533	389
4	120	150	270	82	91	173	50	180	230	57	443	220	213	158	103	944	732	521
5	160	..	160	82	127	209	50	256	306	97	369	260	63	— 2	— 67	1,067	774	481
6	160	..	160	82	267	349	50	405	455	106	509	309	54	— 23	—100	1,188	796	404
7	80	..	80	82	293	375	50	508	558	183	455	328	—103	—185	—267	1,150	648	145
8	..	50	50	82	378	460	50	595	645	185	510	351	—135	—223	—310	1,076	451	—165
9	..	..	..	82	374	456	50	592	642	186	456	324	—186	—267	—348	943	195	—513
10	..	50	50	82	378	458	75	642	717	259	508	329	—209	—291	—373	778	— 96	—886
11	..	..	..	45	376	421	75	642	717	296	421	292	—296	—369	—442	510	—465	—1,328
12	..	..	..	45	376	421	75	642	717	296	421	291	—296	—369	—442	227	—834	—1,770
Wool Price 4s. per lb.																		
1	..	241	241	..	..	..	..	..	..	..	241	241	241	181	121	255	192	128
2	90	82	172	..	15	15	20	..	20	5	187	104	167	141	115	447	353	258
3	120	..	120	82	47	129	40	62	102	—27	249	138	147	113	78	630	494	356
4	90	150	240	82	82	164	40	144	184	20	404	192	220	172	124	901	706	509
5	120	..	120	82	114	196	40	206	246	50	316	225	70	14	— 41	1,029	763	496
6	120	..	120	82	224	306	40	335	375	69	426	261	51	— 14	— 78	1,145	794	443
7	60	..	60	82	246	328	40	419	459	131	388	274	— 71	—139	—208	1,138	694	249
8	..	50	50	82	310	392	40	496	536	144	442	290	— 94	—166	—239	1,107	560	11
9	..	..	..	82	307	389	40	494	534	145	389	263	—145	—211	—276	1,020	370	—265
10	..	50	50	82	309	391	60	534	594	203	441	269	—153	—220	—287	919	159	—552
11	..	..	..	45	309	354	60	534	594	240	354	233	—240	—298	—356	720	—139	—908
12	..	..	..	45	309	354	60	534	594	240	354	232	—240	—298	—356	509	—437	—1,264
Column	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

* Assumptions—see text.

TABLE 4

*Budget of Anticipated Costs and Returns per 100 Acres Aerially Sown and Topdressed**

Wool Price 5s. per lb.

Year	Capital Expenditure			Running Costs			Income				Gross Expenditure		Net Annual Cost			Cumulative Cost + 6% Interest		
	Sheep Purchased	Seed Fertilizer Cultivation Improvements	Total	Fertilizer and Spreading Costs	Dip, Drench, Shearing, Deaths, Replacements	Total	From Existing Sheep	From Extra Sheep	Gross	Net	Total Annual Cost	Amount Allowable for Taxable Deduction	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £
1	..	188	188	..	..	..	..	..	..	..	188	188	188	141	94	199	149	100
2	80	88	168	..	10	10	25	..	25	15	178	108	153	126	99	373	291	211
3	80	100	180	88	35	123	50	52	102	—21	303	151	201	163	125	607	481	356
4	200	..	200	88	72	160	50	103	153	— 7	360	205	207	156	105	862	675	488
5	160	50	210	88	108	196	50	230	280	84	406	294	126	53	— 20	1,048	771	496
6	80	50	130	88	194	282	50	359	409	127	412	317	3	— 76	—155	1,114	737	361
7	80	..	80	88	204	292	50	403	453	161	372	286	— 81	—152	—224	1,095	620	145
8	..	150	150	88	313	401	50	500	550	149	551	296	1	— 73	—147	1,161	580	0
9	..	..	..	88	293	381	50	490	540	159	381	300	—159	—234	—309	1,062	367	—309
10	120	..	120	88	228	316	75	479	554	238	436	323	—118	—199	—280	1,001	178	—589
11	..	..	..	44	346	390	75	625	700	310	390	285	—310	—381	—452	732	—203	—1,041
12	..	..	..	44	346	390	75	625	700	310	390	285	—310	—381	—452	447	—584	—1,493
Wool Price 4s. per lb.																		
1	..	188	188	..	..	..	..	..	..	..	188	188	188	141	94	199	149	100
2	60	88	148	..	10	10	20	..	20	10	158	103	138	112	86	357	277	197
3	60	100	160	88	32	120	40	42	82	—38	280	140	198	163	128	588	466	345
4	150	..	150	88	66	154	40	83	123	—31	304	185	181	135	89	815	637	460
5	120	50	170	88	98	186	40	183	223	37	356	257	133	69	5	1,005	748	493
6	60	50	110	88	165	253	40	292	332	79	363	278	31	— 38	—108	1,098	753	408
7	60	..	60	88	175	263	40	328	368	105	323	243	— 45	—106	—166	1,116	686	257
8	..	150	150	88	258	346	40	417	457	111	496	253	39	— 24	— 87	1,224	702	180
9	..	..	..	88	243	331	40	407	447	116	331	255	—116	—180	—244	1,174	553	— 64
10	90	..	90	88	198	286	60	394	454	168	376	275	— 78	—147	—216	1,162	430	—280
11	..	..	..	44	288	332	60	519	579	247	332	232	—247	—305	—363	970	133	—643
12	..	..	..	44	288	332	60	520	580	248	332	234	—248	—306	—365	765	—173	—1,008
Column	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

* Assumptions—see text.

TABLE 5

*Budget of Anticipated Costs and Returns per 100 Acres Combined—Later Ripped and Resown (RC)**

Wool Price 5s. per lb.

Year	Capital Expenditure			Running Costs			Income				Gross Expenditure		Net Annual Cost			Cumulative Cost + 6% Interest		
$RC1_5$	Sheep Purchased	Seed Cultivation Improvements	Total	Fertilizer and Spreading Costs	Dip, Drench, Shearing, Deaths, Replacements	Total	From Existing Sheep	From Extra Sheep	Gross	Net	Total Annual Cost	Amount Allowable for Taxable Deduction	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £
5	..	100	100	150	107	257	50	246	296	39	357	397	61	— 38	—137	1,065	736	407
6	160	..	160	82	223	305	50	298	348	43	465	267	117	50	— 17	1,253	833	413
7	160	..	160	82	247	329	50	399	449	120	489	302	40	— 35	—110	1,371	846	321
8	160	..	160	82	295	377	50	507	557	180	537	344	— 20	—106	—192	1,432	784	137
9	80	50	130	82	342	424	50	614	664	240	554	358	—110	—199	—289	1,401	620	— 152
10	..	100	100	82	409	491	75	750	825	334	591	377	—234	—328	—422	1,237	310	—574
11	..	..	..	45	409	454	75	747	822	368	454	336	—368	—452	—536	921	—142	—1,110
12	..	..	..	45	409	454	75	744	819	365	454	330	—365	—447	—530	589	—589	—1,640
$RC1_7$																		
7	..	100	100	150	283	433	50	508	558	125	533	476	— 25	—144	—263	1,232	655	150
8	120	..	120	82	270	352	50	492	542	190	472	333	— 70	—153	—236	1,232	564	— 86
9	120	50	170	82	286	368	50	546	596	228	538	346	— 58	—144	—230	1,244	445	— 316
10	..	100	100	82	409	491	75	748	823	332	591	363	—232	—323	—414	1,073	129	— 730
11	..	..	..	45	409	454	75	745	820	366	454	330	—366	—448	—530	749	—319	—1,260
12	..	..	..	45	409	454	75	745	820	366	454	330	—366	—448	—530	406	—767	—1,790
RC1																		
8	..	100	100	150	377	527	50	615	665	138	627	509	— 38	—165	—292	1,179	512	— 147
9	80	..	80	82	287	369	50	532	582	213	449	330	—133	—215	—298	1,109	315	— 445
10	80	50	130	82	326	408	75	647	722	314	538	344	—184	—270	—356	981	48	— 801
11	..	100	100	45	409	454	75	745	820	366	554	330	—266	—348	—431	758	—300	—1,232
12	..	..	..	45	409	454	75	745	820	366	454	330	—366	—448	—531	415	—748	—1,763

* Assumptions—see text.

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TABLE 6

*Budget of Anticipated Costs and Returns per 100 Acres Combined—Later Ripped up and Resown**

Wool Price 4s. per lb.

Year	Capital Expenditure			Running Costs			Income				Gross Expenditure		Net Annual Cost			Cumulative Cost + 6% Interest		
$RC1_5$	Sheep Purchased	Seed Cultivation Improvements	Total	Fertilizer and Spreading Costs	Dip, Drench, Shearing, Deaths, Replacements	Total	From Existing Sheep	From Extra Sheep	Gross	Net	Total Annual Cost	Amount Allowable for Taxable Deduction	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £	No Tax Deduction	Tax at 5s. 0d. in £	Tax at 10s. 0d. in £
5	..	100	100	150	94	244	40	206	246	2	344	363	98	7	— 84	1,059	756	451
6	120	..	120	82	186	268	40	250	290	22	388	228	98	41	— 16	1,226	845	461
7	120	..	120	82	209	291	40	329	369	78	411	254	42	— 21	— 85	1,344	873	399
8	120	..	120	82	250	332	40	415	455	123	452	289	— 3	— 75	—147	1,421	846	267
9	60	50	110	82	288	370	40	505	545	175	480	289	— 65	—137	—209	1,437	752	61
10	..	100	100	82	339	421	60	620	680	259	521	309	—159	—236	—313	1,355	547	—252
11	..	..	..	45	339	384	60	618	678	294	384	271	—294	—362	—430	1,125	196	—682
12	..	..	..	45	339	384	60	617	677	293	384	267	—293	—360	—426	882	—164	—1,108
$RC1_8$																		
8	..	100	100	150	309	459	40	496	536	77	559	418	23	— 81	—186	1,231	650	67
9	60	..	60	82	244	326	40	440	480	154	386	265	— 94	—160	—226	1,205	519	—159
10	60	50	110	82	276	358	60	535	595	237	468	281	—127	—197	—267	1,143	341	—426
11	..	100	100	45	339	384	60	618	678	294	484	267	—194	—261	—328	1,006	85	— 754
12	..	..	..	45	339	384	60	618	678	294	384	267	—294	—361	—428	755	—276	—1,182

* Assumptions—see text.

TABLE 7

Period and Extent of Debt for Pasture Establishment Techniques at Various Tax Rates

Method	Wool Price	Years Before Annual Receipts Exceed Annual Expenditures			Years Before Accumulated Total Receipts Exceed Sum of Yearly Expenditure and 6 Per Cent Interest			Time and Amount of Greatest Debt					
		Tax Rate			Tax Rate			Tax Rate					
		Nil	5s. 0d. in £	10s. 0d. in £	Nil	5s. 0d. in £	10s. 0d. in £	Nil		5s. 0d. in £		10s. 0d. in £	
								Year	£	Year	£	Year	£
	s. d.												
PSB ..	5 0	3	3	3	11	8	6	4	1,540	3	1,270	3	1,022
	4 0	3	3	3	12	9	7	5	1,477	3	1,140	3	916
COM ..	5 0	6	4	4	12	9	7	6	1,188	6	796	4	521
	4 0	6	5	4	14	10	8	6	1,145	6	794	4	509
ATD ..	5 0	8	5	4	13	10	7	8	1,161	5	771	5	496
	4 0	8	5	5	15	11	8	8	1,224	6	753	5	493
RCI_5 ..	5 0	7	6	4	13	10	8	8	1,432	7	846	6	413
	4 0	7	6	4	14	11	9	9	1,437	7	873	6	461
RCI_8 ..	5 0	6	4	4	13	10	7	6	1,188	6	796	4	521
	4 0	8	5	4	14	11	8	8	1,231	6	794	4	509

For PSB and RCI_5 the year of receipts exceeding payments is not the same as the year of maximum indebtedness because of interest charges.

(*d*) *Combining Later Ripped up and Resown* (See Tables 5, 6)

All expenses are as for COM until the year of resowing when £100, £76 and £74 were allowed for seed, cultivation costs and fertilizer respectively. In later years £150 was set aside for capital improvements such as yards and extensions to the wool shed.

Some Implications of These Assumptions

Many authors[20] have commented that the long period before the capital investment is returned is a notable feature of the economics of pasture improvement. This aspect is illustrated in Table 7, summarizing aspects of Tables 2-6. A single year's sowing will take from three to eight years depending on the sowing method, before annual receipts exceed annual expenses. This would scarcely appear a cheerful prospect to a grazier needing quick returns to meet the cost-price squeeze! If all the money were borrowed (except that obtained by reinvesting the profits due to the sowing) at 6 per cent it would take from 11 to 15 years, depending on the wool price and sowing technique, before the money could be repaid. Few bankers would willingly countenance an overdraft for such a period although indirectly they may do so because the needs arise over time, not just in one year.

The effect of a slow build up in stock numbers, and hence in income, with ATD is indicated by the maximum indebtedness being not very much lower than that of PSB despite the much lower initial costs. This also is affected by interest payments and the constant 25s. 0d. per head of sheep capital loading, although considerably fewer sheep are carried. This shows that the apparent low cost of ATD may be illusionary in the long run, especially if the money is borrowed. The effect is diminished of course if a higher carrying capacity is assumed for ATD.

The time lag for recovering capital is markedly increased if some of the extra income is used to raise living standards rather than to retire debt or for reinvestment. The period of indebtedness increases too as *successive* rather than *single* sowings are considered.

These figures may help to explain why many people have not yet begun a programme of pasture improvement. Pasture improvement may decrease a grazier's vulnerability to the cost price squeeze but the prospect of many years indebtedness may be a significant deterrent.

Land

The Size of the Property

A 1000 acres was used as the property size so that the results could easily be adapted for other properties. One factor which inhibits this is that of the labour. One man would need casual labour to work a 1000 acre fully improved property at the stocking rates assumed here. A 1400 acre property might be one man unimproved but would require two men after development. Therefore the optimum plan for such a property might not be 1.4 times that for the 1,000 acre because labour costs have not been included. In short the findings of the study could only be extended to

[20] For example, Gruen, 1956, *op. cit.*, Gruen and Pearse, *op. cit.*, and Campbell and Shand, *op. cit.*, Numerous other examples could be quoted.

situations where existing labour force could handle the extra stock. This includes the possibility of diversion of men who were previously clearing or fencing to stock work.

Sowing Restraints

In the introduction it was suggested that restraints such as labour, machinery availability, fear of drought, fear of introducing disease or inferior stock, and fear of losing capital invested in ground preparation and seed, as well as lack of capital may affect the area to be sown in any one year. If bloat were not a serious problem the use of cattle would overcome some of these restraints.

(*a*) *Prepared Seed Bed*

PSB was originally limited by considering the likely capacity of the machinery available on a 1,000 acre property and was set at 150 acres or 15 per cent of the property. Later discussion with farmers and graziers suggested that 10 per cent might have been a better figure. However Table 8 indicates that graziers may sow substantially more than 10 per cent of the property in one year. Also the results indicate that at expected levels of finance capital restricts sowings well below the limits imposed here.

Table 8

Areas Sown per Annum Expressed as a Percentage of Farm Sown *

Farm	Acreage	No. of Sowings	Total Area Sown	Average Area Sown		Largest Area Sown	
				Acres	Proportion of Farm	Acres	Proportion of Farm
					Per cent		Per cent
A	1,764	14	2,289	164	9·3	310	17·6
C	5,554	7	2,242	320	5·7	1,116	20·0
D	3,658	5	2,297	459	12·5	610	16·6
E	6,172	6	3,520	587	9·5	1,043	16·9
F	1,046	5	1,025	205	19·6	376	35·9
Total	18,194	37	11,373	307	10·1	..	..

* Adapted from Campbell and Shand, *op. cit.*, Table 1. A 32-acre sowing at the beginning period was excluded from Farm C, the two small initial sowings from Farm E, and the first sowing on Farm F, because it was held that at this early stage the area sown may be unrepresentative. An eight acre final sowing in D was also excluded because it seemed unrepresentative.

(*b*) *Combining*

Combining was set at 300 acres as no special management of existing stock was assumed necessary, so only machine capacity and risk aversion would be effective limits.

(*c*) *Aerial Sown and Topdressed*

As there is no drain on farm resources other than capital theoretically the whole property could be sown in one year. However risk aversion may

be an important restraint and the limit was set at 500 acres. The effect of a drought failure may be small as there is little investment in seed and presumably the fertilizer will be of benefit in later years.

(d) Combining Ripped up and Resown

This acreage was set at 200 acres in the year of resowing. The previous fertilizer and clover growth was presumed to have raised fertility to such an extent that seed bed preparation need not be quite as thorough as for PSB and it was also presumed that improved pastures would be better able to stand the strain imposed by the stocking stress.

The Objective to be Maximized

One problem in a pasture improvement study is to decide on what objective to maximize. Should it be the establishment of a dense, even sward in a short time, the sowing method which gives the best establishment of grasses, the number of sheep to be carried in a given period, to minimize income tax payments or to give the greatest return on capital invested? Due to lower wool prices most graziers seem to consider that the aim is to maximize profit so the greatest possible net income in the first twenty years from beginning the programme was used as the criterion in this study.

Net income is defined as the gross income from wool and sheep sales less the cost of replacing deaths and culls, pasture maintenance and the variable costs of running sheep such as shearing, dips, and drenches. It is not net in the sense that shire rates, machinery depreciation, labour and other fixed charges have been taken into account but in the sense that it is the net addition to profitability due to the improvements undertaken.

The value used in the objective function for any given year and method of establishment is shown in Table 9, column headed "No Tax". These values have been derived from the data in Tables 2, 3, 4, 5, and 6. The net income shown for year 12, column 11, in these tables is assumed to be the net income for each of the years 13 to 20, for a sowing in the first year. To obtain the value of a year 1 sowing the net incomes shown in the appropriate table, are summed, e.g., for PSB 1, sum the net incomes shown in column 11, Table 2 plus eight times that of year 12, to get the sum of net incomes for 20 years from first sowing. For a year 2 sowing there will only be nineteen years for returns to accumulate so PSB2 would be the sum of column 11, Table 2 plus seven times year 12, PSB3 would be the sum of column 11 plus six times year 12, and so on. For PSB9 (or COM9 or ATD9) the net income is that obtained by summing column 11 of Table 2 (or 3 or 4) and for PSB10 (or COM10 or ATD10) it is the sum of the net income shown for year 1-11. In the case of RC methods one first sums the net income of Table 3 for an appropriate period and then turns to the relevant section of Table 5 or 6.

Table 9 also shows disposable income after income tax has been levied at either 5s. 0d. or 10s. 0d. in the pound. Allowance was made on an arbitrary basis for capital expenditures which are wholly or partly allowable as taxation deductions (see column 13, Tables 2-6, for the sum of allowable deductions. This compares with net income which is column 10—less column 7).

TABLE 9

Sum of Net Income for 20 *Year Period from Start of Programme at Various Tax Rates*

Wool Price 5*s.*

Year	PSB			COM			ATD			$RC1_5$, 2_6, 3_7, 4_8, 5_9 and 6_{10}			$RC1_8$, 2_9, 3_{10}, 4_{11} and 5_{12}		
	Tax Rate			Tax Rate			Tax Rate			Tax Rate			Tax Rate		
	Nil	5s. 0d. in the £	10s. 0d. in the £	Nil	5s. 0d. in the £	10s. 0d. in the £	Nil	5s. 0d. in the £	10s. 0d. in the £	Nil	5s. 0d. in the £	10s. 0d. in the £	Nil	5s. 0d. in the £	10s. 0d. in the £
1	5,463	3,908	2,604	4,038	2,814	1,875	4,004	2,771	1,846	4,728	3,234	2,160	4,773	3,196	2,134
2	5,097	3,626	2,416	3,742	2,586	1,723	3,694	2,533	1,687	4,362	2,953	1,972	4,407	2,915	1,946
3	4,731	3,344	2,228	3,446	2,358	1,571	3,384	2,295	1,528	3,996	2,672	1,784	4,041	2,634	1,758
4	4,365	3,062	2,040	3,150	2,130	1,419	3,074	2,057	1,369	3,630	2,391	1,596	3,675	2,353	1,570
5	3,999	2,780	1,852	2,854	1,902	1,267	2,764	1,819	1,210	3,264	2,110	1,408	3,309	2,072	1,382
6	3,633	2,498	1,664	2,558	1,674	1,115	2,454	1,581	1,051	..	..	..	..	..	..
7	3,275	2,214	1,475	2,262	1,446	963	2,144	1,342	892	..	..	..	..	..	..
8	2,914	1,934	1,288	1,966	1,225	816	1,834	1,103	733	..	..	..	..	..	..
9	2,545	1,650	1,099	1,670	1,004	669	1,524	864	574	..	..	..	..	..	..
10	2,179	1,370	912	1,374	791	527	1,214	648	430	..	..	..	..	..	..
	Wool Price 4*s.*														
1	4,228	3,100	2,061	3,140	2,233	1,487	3,044	2,159	1,440	3,605	2,553	1,699	3,656	2,518	1,670
2	3,934	2,873	1,910	2,900	2,047	1,363	2,796	1,967	1,312	3,311	2,326	1,548	3,362	2,291	1,519
3	3,640	2,646	1,759	2,660	1,861	1,239	2,548	1,775	1,184	3,017	2,099	1,397	3,068	2,064	1,368
4	3,346	2,419	1,608	2,420	1,675	1,115	2,300	1,583	1,056	2,723	1,872	1,246	2,770	1,837	1,217
5	3,052	2,192	1,457	2,180	1,489	991	2,052	1,391	928	2,429	1,645	1,095	2,480	1,610	1,066
6	2,758	1,965	1,306	1,940	1,303	867	1,804	1,199	800	..	..	..	..	..	..
7	2,470	1,738	1,155	1,700	1,119	743	1,556	1,007	672	..	..	..	..	..	..
8	2,178	1,513	1,005	1,460	940	624	1,308	815	544	..	..	..	..	..	..
9	1,880	1,283	852	1,220	761	505	1,060	623	416	..	..	..	..	..	..
10	1,586	1,056	701	980	590	391	812	453	303	..	..	..	..	..	..

These figures have not been discounted. That is, the values of Table 9 do not show the "present value" of the future incomes, discounted at an appropriate interest rate, but simply the sum of the flow. To determine the effect of discounting a check programme was computed using a discount rate of 10 per cent. Compared with the results without discounting the revenue at any given level of capital expenditure did not differ by more than 4 per cent and usually by much less than this. The same activities entered the general solution but the levels of capital at which they entered and were displaced showed some differences, as did the maximum acreages attained.

In view of these relatively minor changes in solution and as time was at a premium it was decided that discounting was not worth the time it would take. Several factors may affect this somewhat surprising result of lack of sensitivity to discounting. The ratio between the values in the objective function rather than their values as such are important, i.e., the result would be the same if three activities had values of either £1,000, £2,000 and £1,500 or £1, £2 or £1.5. Discounting emphasizes the near future and so one would expect sowings to be done in the early years. The methods of calculating the values of Table 9 also emphasize the early years so there is a possibility that the ratios between the discounted and undiscounted values may be similar. The extent to which this is so is shown in Table 10, where PSB1 has a value of one whether discounted or undiscounted. The ratios of all other activities and PSB1 are shown undiscounted with the ratio for the discounted values shown in the lower section of the table. The discount rate is 10 per cent[21] and figures are rounded to two places of accuracy.

Using exact figures we find that in a comparison of PSB and ATD undiscounted an ATD sowing must be carried out four years before a PSB if it is to be superior, e.g., ATD2 is better than PSB6 but inferior to PSB5, and so on. This is true for the discounted figures for the first five years but we find that ATD6 equals PSB9 and ATD7 is superior to PSB10. Similarly a comparison of PSB and $RC1_8$ shows a two year lag for either the discounted or undiscounted values. The only marked change is between PSB and COM where undiscounted COM is about equal to PSB sown four years later but after discounting the disparity is reduced to three years.

The use of a 20-year period distorts the effect of discounting, especially where one is comparing a large future flow as in PSB10 with a smaller one such as ATD10. How great this will be depends in part on how high is the discount rate used. Still this may account for the change in ranking of PSB and ATD mentioned in the previous paragraph.

[21] Ten per cent has been used because the author considers this to be about the lowest return at which one can safely recommend farm investment in view of its inherent riskiness. Nevertheless the discount rate should vary depending on individual circumstances. A farmer who has little capital has high return avenues for its use, whilst one with unlimited capital will have already used it to get the high returns and would be willing to accept (or use in his investment decisions) a lower rate. However off farm comparisons are valid and unless he favours risk presumably he will require a higher return for farm investments than for secure non farm investments.

TABLE 10

Comparison of the Ranking of Discounted and Undiscounted Income Flows
Wool 5s. per lb.

Method	Year of Establishment									
	1	2	3	4	5	6	7	8	9	10
				Undiscounted						
PSB	1	·93	·87	·80	·73	·66	·60	·53	·47	·40
COM	·74	·68	·63	·58	·52	·47	·41	·36	·31	·25
RCI_8	·87	·81	·74	·67	·61	..	..	..	..	..
ATD	·73	·68	·62	·56	·51	·45	·39	·34	·28	·22
				Discounted at 10 per cent						
PSB	1	·88	·77	·67	·58	·51	·44	·37	·31	·25
COM	·68	·60	·52	·45	·39	·33	·28	·23	·19	·15
RCI_8	·78	·68	·59	·51	·44	..	..	..	..	..
ATD	·65	·57	.48	·43	·36	·31	·26	·21	·17	·13

We show later that quite large changes from the optimum plan may have little effect on revenue. This may be another reason why discounting seems to exert little effect. Even if one thinks of the solution as being that of deciding what would be best in year 1, then year 2, and so on we find that discounting has no effect on the ranking of the methods.

Whilst only one set of maximizing values has been analysed in the manner of Table 10 inspection of the others indicates no reason to suppose the results would differ as the values are of a similar order to those used to construct Table 10. Discounting would produce different plans to those shown below, but it is believed that they would not be significantly different at the extension or advisory level.

4. THE MATRIX

There have been many articles and books written in the last decade to explain the mathematical form and methods of solving linear programmes. These details need not concern us here and readers who seek a readily available outline of the mathematical form could refer to Gruen or Throsby.[22]

For convenience of exposition it is sufficient to state that linear programming is a means by which a number of *activities,* in this case a given year and method of pasture establishment, can be considered in relation to a number of *restraints,* in this case the amount of capital available, the size of the property and the yearly acreage permitted to be sown, in such a way that the *objective* is maximized (the sum of annual net incomes over 20 years is the object).

[22] Gruen, 1959, *op. cit.*, Throsby, *op. cit.*

TABLE 11

Matrix for Wool 5s., no Clearing Costs, Savings Financed—Property Development Plan

		"b" Column	Capital Supply	PSB1	PSB2	PSB3	PSB5	PSB6	PSB7	PSB8	PSB9	PSB10	COM2	COM8	COM9	COM10	ATD1	ATD2
Cj				5,463	5,097	4,731	3,999	3,633	3,275	2,914	2,545	2,179	3,742	1,966	1,670	1,374	4,004	3,694
Capital Supply			1															
Capital Year	1		— 1	577													199	
	4		— 4	1,540	1,520	947							677				859	603
	5		— 5	1,519	1,540	1,520	557						943				1,044	859
	6		— 6	1,426	1,519	1,540	947	557					1,066				1,110	1,044
	7		— 7	1,272	1,426	1,519	1,520	947	557				1,187				1,091	1,110
	8		— 8	1,102	1,272	1,426	1,540	1,520	947	557			1,149	255			1,157	1,091
	9		— 9	813	1,102	1,272	1,519	1,540	1,520	947	557		1,075	474	255		1,058	1,157
	10		—10	529	813	1,102	1,426	1,519	1,540	1,520	947	557	942	677	474	255	996	1,058
	11		—11	179	529	813	1,272	1,426	1,519	1,540	1,520	947	777	943	677	474	728	996
	12		—12	—187	179	529	1,102	1,272	1,426	1,519	1,540	1,520	529	1,066	943	677	443	728
Land Supply		1,000		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Yearly Sowing Limit	1	150		100													30	
	2	150			100								50					30
	3	150				100												
	4	150																
	5	150					100											
	6	150						100										
	7	150							100									
	8	150								100				50				
	9	150									100				50			
	10	150										100				50		
	11	150																
		j =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

All figures should be preceded by a sign. Only negative signs have been shown.

TABLE 11—*continued*

	"b" Column	Capital Supply	ATD9	ATD10	$RC1_8$	$RC2_9$	$RC3_{10}$	$RC4_{11}$	$RC5_{12}$	$RC1_7$	$RC2_8$	$RC3_9$	$RC5_{11}$	$RC6_{12}$	$RC2_6$	$RC5_9$	*i*
C-	..	..	1,524	1,214	4,773	4,407	4,041	3,678	3,309	4,800	4,434	4,068	3,336	2,971	4,362	3,264	..
Capital Supply	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Capital Year 1	..	— 1	..	..	255	..	..	..	..	255	..	..	..	..	..	..	2
4	..	— 4	..	..	943	677	474	255	..	943	677	474	..	..	677	..	3
5	..	— 5	..	..	1,066	943	677	474	255	1,066	943	677	255	..	943	255	4
6	..	— 6	..	..	1,187	1,066	943	677	474	1,187	1,066	943	474	255	1,064	474	5
7	..	— 7	..	..	1,149	1,187	1,066	943	677	1,232	1,187	1,066	677	474	1,252	677	6
8	..	— 8	..	..	1,178	1,149	1,187	1,066	943	1,232	1,232	1,187	943	677	1,369	943	7
9	..	— 9	199	..	1,108	1,178	1,149	1,187	1,066	1,244	1,232	1,232	1,066	943	1,430	1,004	8
10	..	—10	373	199	979	1,108	1,178	1,149	1,187	1,073	1,244	1,232	1,187	1,066	1,392	1,252	9
11	..	—11	603	373	756	979	1,108	1,178	1,149	749	1,073	1,244	1,232	1,187	1,235	1,369	10
12	..	—12	859	603	413	756	979	1,108	1,178	406	749	1,073	1,232	1,232	919	1,430	11
Land Supply	..	1,000	..	100	100	100	100	100	100	100	100	100	100	100	100	100	12
Yearly Sowing Limit	1	150		..	..	50	..	..	..	..	50	..	..	..	..	..	..	13
	2	150	..	..	..	..	50	..	..	..	..	50	..	..	..	50	..	14
	3	150	..	..	..	..	..	50	..	..	..	..	50	..	..	..	..	15
	4	150	..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	16
	5	150	..	..	..	..	..	..	..	50	..	..	..	50	..	..	50	17
	6	150	..	..	..	..	..	..	..	..	..	..	..	..	50	75	..	18
	7	150	..	..	..	..	..	..	..	..	75	..	..	..	..	..	..	19
	8	150	..	..	..	75	..	..	..	..	..	75	..	..	..	..	..	20
	9	150	..	30	..	..	75	..	..	..	..	..	75	..	..	..	75	21
	10	150	..	..	30	..	..	75	..	..	..	..	..	75	..	..	..	22
	11	150	..	..	..	..	..	..	75	..	..	..	..	..	..	..	..	23
		j =	1	17	18	19	20	21	22	23	24	25	26	27	28	29	30	..

The actual matrix for wool at 5s. 0d. per lb., no clearing costs, and capital to be supplied from savings is shown in Table 11. There are 30 activities (the columns labelled *j*). Each activity has coefficients (which we call *a*) indicating its "requirements" of the various *limitations* or *restraints*. A positive coefficient indicates that activity uses the restraint, a zero coefficient indicates non-use or no requirement, and a negative coefficient means the activity will add to the supply of the limiting resource.

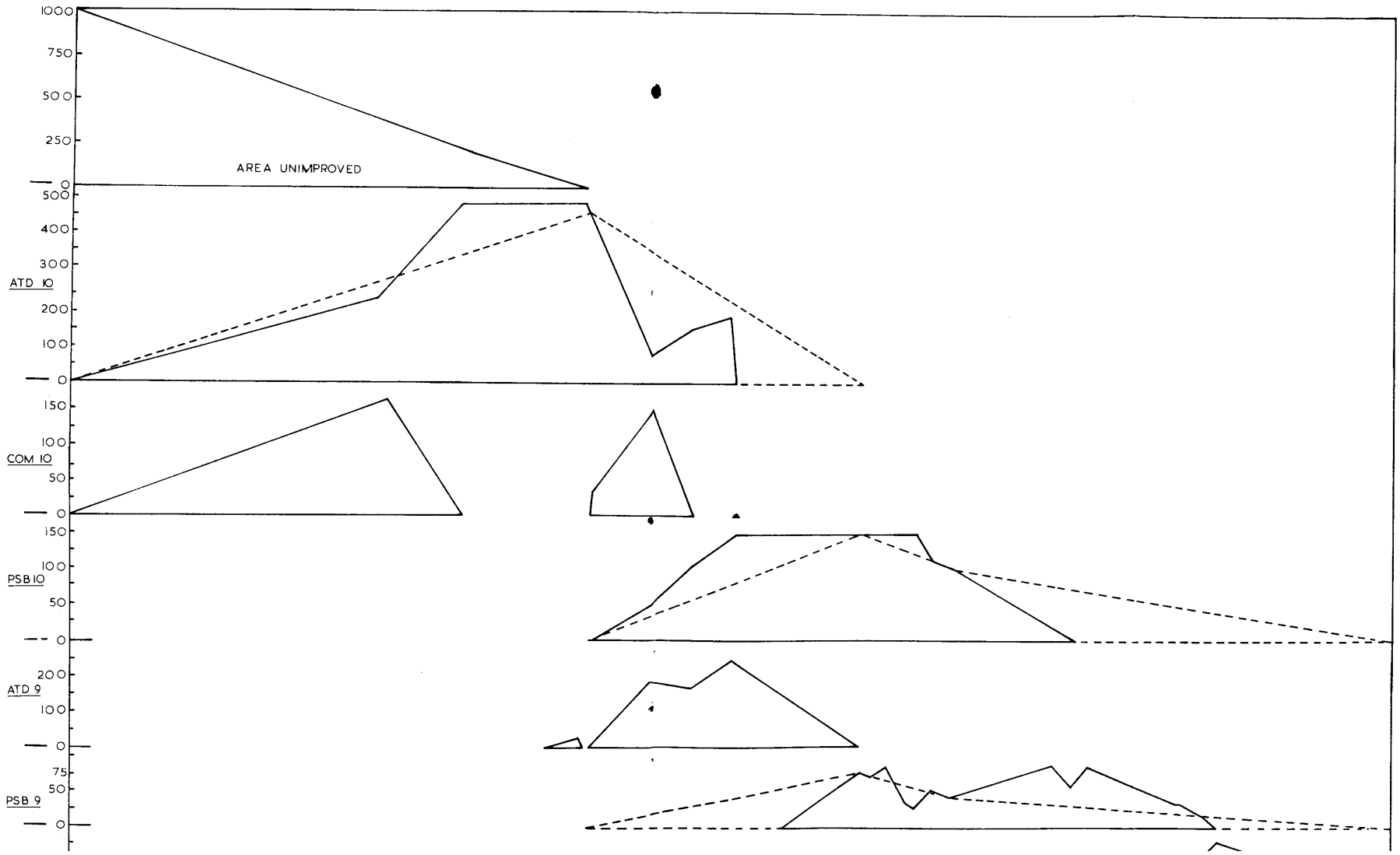
The first activity supplies capital. This activity makes it possible to vary capital over any given range. The introduction of a unit of this activity would supply £1 of capital to year 1, £4 to year 4, £10 to year 10, etc. This means that capital is being supplied in such a way that any capital not used in the year supplied can be saved until a later period,[23] e.g., a person saving £100 p.a. would have £100 in the first year, £400 in the fourth year, and so on. The capital requirement is calculated so that if £50 is needed in the first year and £70 in the second the actual amount specified in the second year would be £120. Therefore, in the example cited there would be £50 unused in the first year and £80 in the next year. Thus, if the third year needed £180 the requirements would appear as £300 and by using the £80 saved the demand would be met. There would be no savings left over for year 4. Another point to note is that a constant rate of saving (or introducing capital from existing earnings) is imposed, for each successive year. As suggested in footnote 23 this could easily be changed if some other possibility was desired.

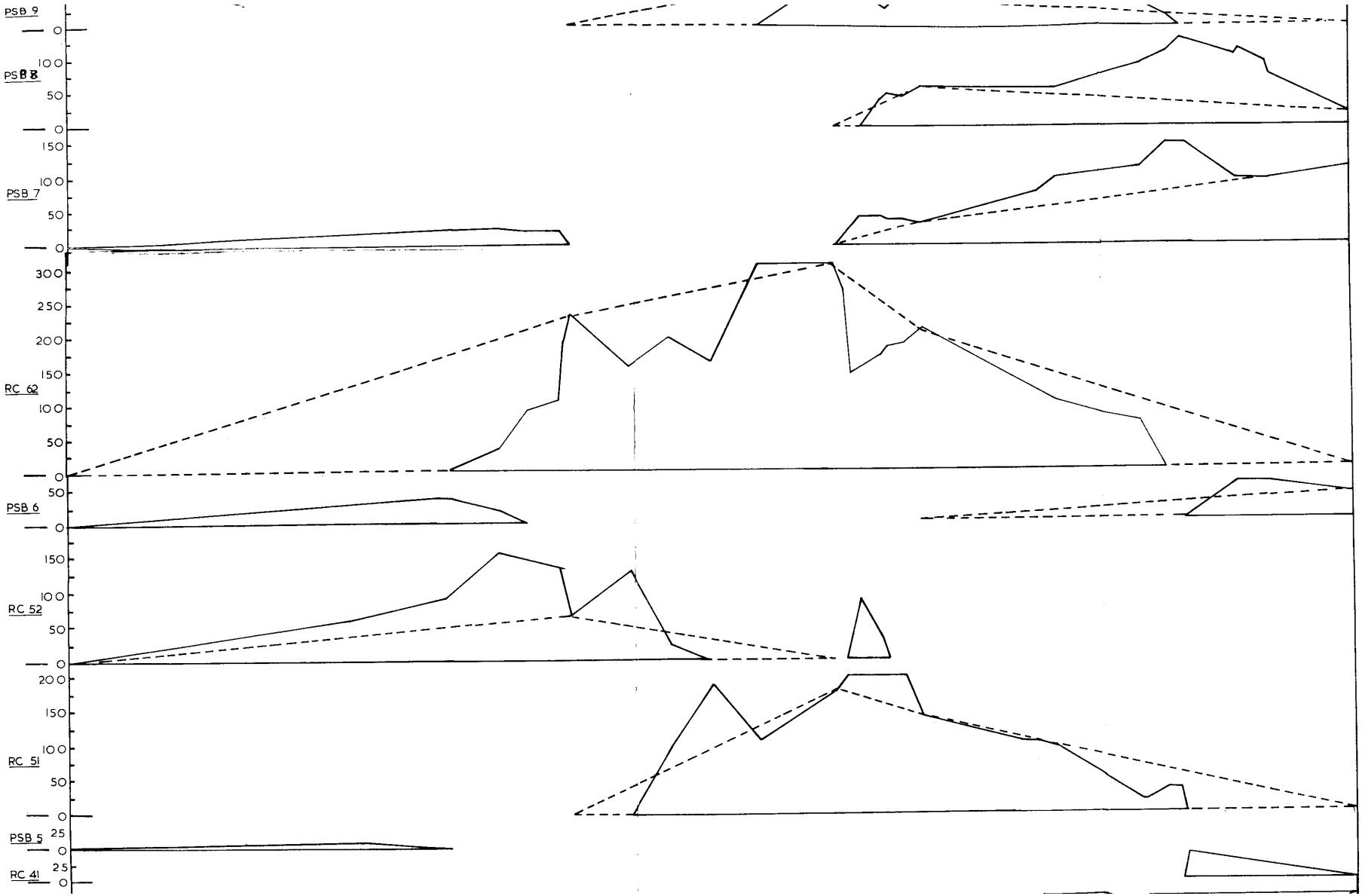
The activities $j = 2$–30 represent the requirements for capital and land of PSB1–3, 5–10, COM2, 8–10, ATD1, 2, 9, 10, $RC1_8$–5_{12}, $RC1_7$–3_9, 5_{11}, 6_{12} and $RC2_6$, 5_9. (The remaining activities which would be needed if all four methods were to have ten opportunities of entering would have exceeded the capacity of the computer. By reducing the number of land restraints all the activities were included in a programme. The resulting solution was studied and those activities which entered the solution as well as those whose Z–C values showed they were close to entering were selected for study at the 5s. 0d. wool price.)

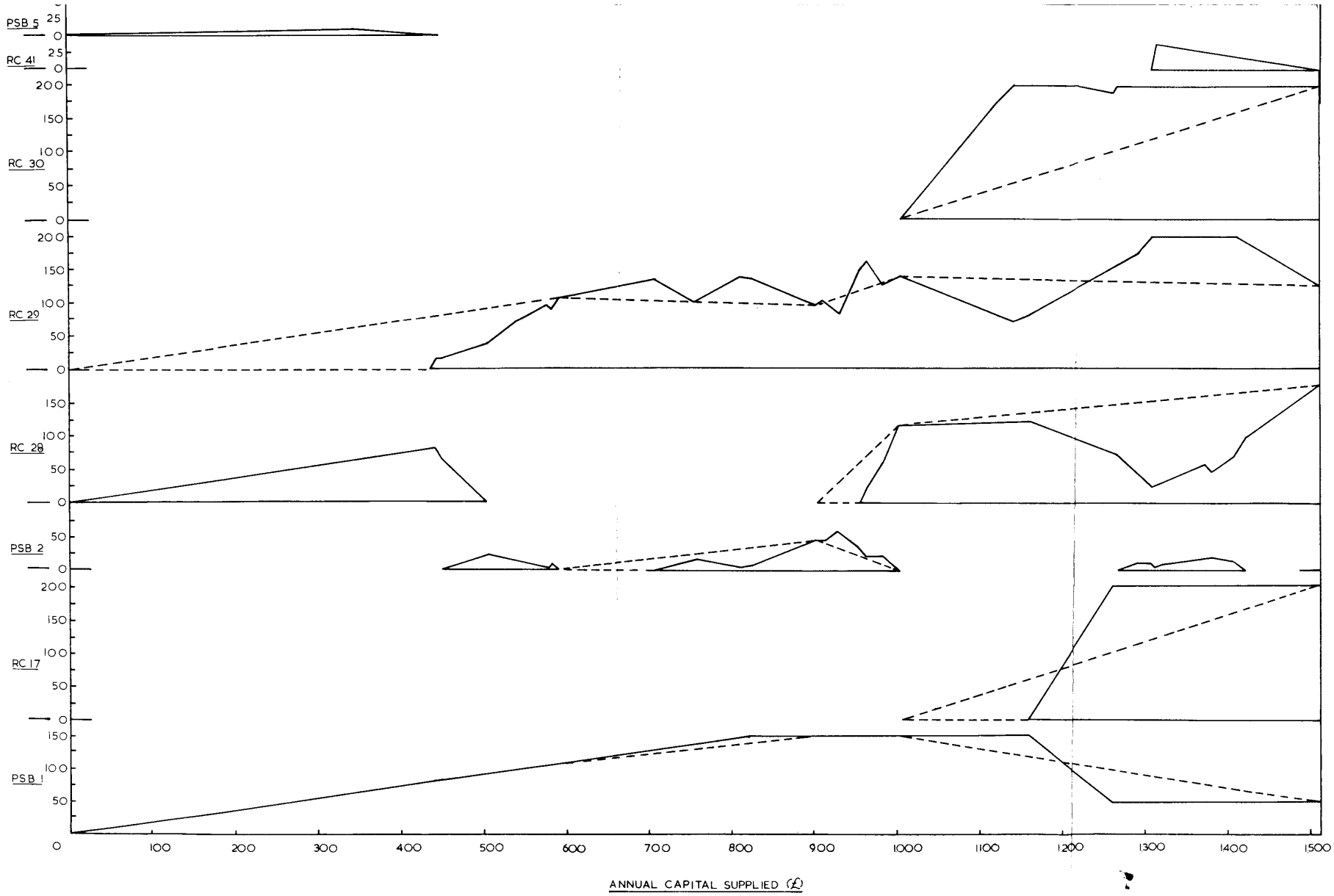
There remains one column, the "b", or basis column, unexplained. Broadly, this column gives a solution to the problem. The original entries in it are the initial supplies of the limiting resources or other restraints. The first "solution" would be to make no use of resources and have no profit. The linear programme solution progressively replaces these resources by activities so that at any stage the figures in the "b" column indicate the level of the introduced activities and the level of those resources which are still in supply. (Introduction of an activity would mean the complete using up of the resource which it replaces.) The figures appearing initially in the "b" column are best explained by considering the various limitations.

[23] Capital could be supplied in any way desired. If it was deemed unreasonable to save capital from year to year then the coefficients would all be –1, instead of –1, –4, –5, –6, –7, –8, –9, –10, –11, –12. Equally, if it were known that in one year, perhaps the fifth, no capital would be available due to a drought and that in the seventh year we could save three times as much due to an increase in prices, these figures could be incorporated and the capital supply activity would read, –1, –4, –4, –5, –8, –9, –10, –11, –12, –13.

Fig. 1. Ten Year Sowing Plans, Wool 5s. 0d. As Savings Rise from £0 to £1,525 Annually. Dashed Lines Show A Simple Plan For Advisory Work.




PSB 9
0
PSB 8
100
50
0
150
PSB 7
100
50
0
300
250
200
RC 62
150
100
50
0
50
PSB 6
0
150
RC 52
100
50
0
200
150
RC 51
100
50
0
PSB 5
25
0
RC 41
25
0


PSB 5
25
0
RC 41
25
0
200
150
100
RC 30
50
0
200
150
100
RC 29
50
0
150
100
RC 28
50
0
50
PSB 2
0
200
150
100
RC 17
50
0
150
100
PSB 1
50
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
ANNUAL CAPITAL SUPPLIED (£)

In Table 11 the 23 restraints (or rows) have been labelled "*i*". The first restraint is actually a row required to permit the level of capital invested to be varied parametrically and is not a restraint in the usual sense of the term.

The restraints $i = 2\text{-}11$ are concerned with the capital available in year 1 and years 4-12 respectively. Years two and three did not usually prove limiting and were excluded to allow more activities to be considered.

The restraint $i = 12$ is the size of the property. All activities other than capital supply use up land when they are introduced. In addition they will use up part of the supply in one or other of restraints $i = 13\text{-}23$, the limitations on area to be sown in each of the years one to eleven. Year 11 is included because some RC activities require coefficients in that year, although all initial sowings are completed by year ten.

The figures in the "b" column are zero for $i = 1\text{-}11$ because we assume zero capital until the first activity is introduced. The property size of 1,000 acres is shown in $i = 12$. The figure of 150 is used in $i = 13\text{-}23$ to provide an upper limit on the area sown in a given year.

Finally let us consider the activity coefficients. The coefficients $i = 2\text{-}11$, have been obtained from the "Cumulative Cost + 6 per cent Interest" "No Tax Deduction" column of Table 2 for $j = 2\text{-}10$, of Table 3 for $j = 11\text{-}14$, of Table 4 for $j = 15\text{-}18$, and Table 5 for $j = 19\text{-}30$. They show the capital required by the respective activities in the first, fourth, fifth, sixth, seventh, eighth, ninth, tenth, eleventh and twelfth years from starting the pasture programme. Note that this formulation of the capital supply means that an activity is supplying capital as soon as its capital coefficients stop rising. So all the early activities are supplying capital in later years despite the fact that only PSB1 ($i = 2$) has a negative coefficient in the capital rows.

The sowing restraints of 150, 300, 500 and 200 acres in any one year for PSB, COM, ATD and RC are exercised by the coefficients of $i = 13\text{-}23$, $j = 2\text{-}30$. For example the coefficient $a_{13,\ 2}$ is 100 which divided into the supply (b column, $b_{13} = 150$) would permit 150 acres of PSB1. The coefficient $a_{14,\ 11}$ is 50 and this divided into the supply $a_{14} = 150$ would allow 300 acres of COM2. The RC activities require two coefficients, 50 for the year combined and 75 for the year of resowing. In any one year there could be a combination of activities. The coefficients of 30 (ATD), 50 (COM), 75 (RC) and 100 (PSB) would allow innumerable combinations but an example is 50 acres of PSB9, 100 acres of COM9, 75 acres of $RC2_9$ and about 97 acres of ATD9, which would exhaust the restraint i_{21}. Clearly in such a case an increase in the area sown by one method must be at the expense of one or more of the other methods.

Having set the problem, formulated the activities, and defined the objective, it remains to report the results and derive the conclusions.

5. RESULTS AND DISCUSSIONS

Two solutions of the general problem are presented, namely, development out of savings, without considering the effects of income tax, for wool prices of either 5s. 0d. or 4s. 0d. per lb. The first result is discussed in detail but only the major points and differences from the 5s. 0d. plan are discussed in the second case.

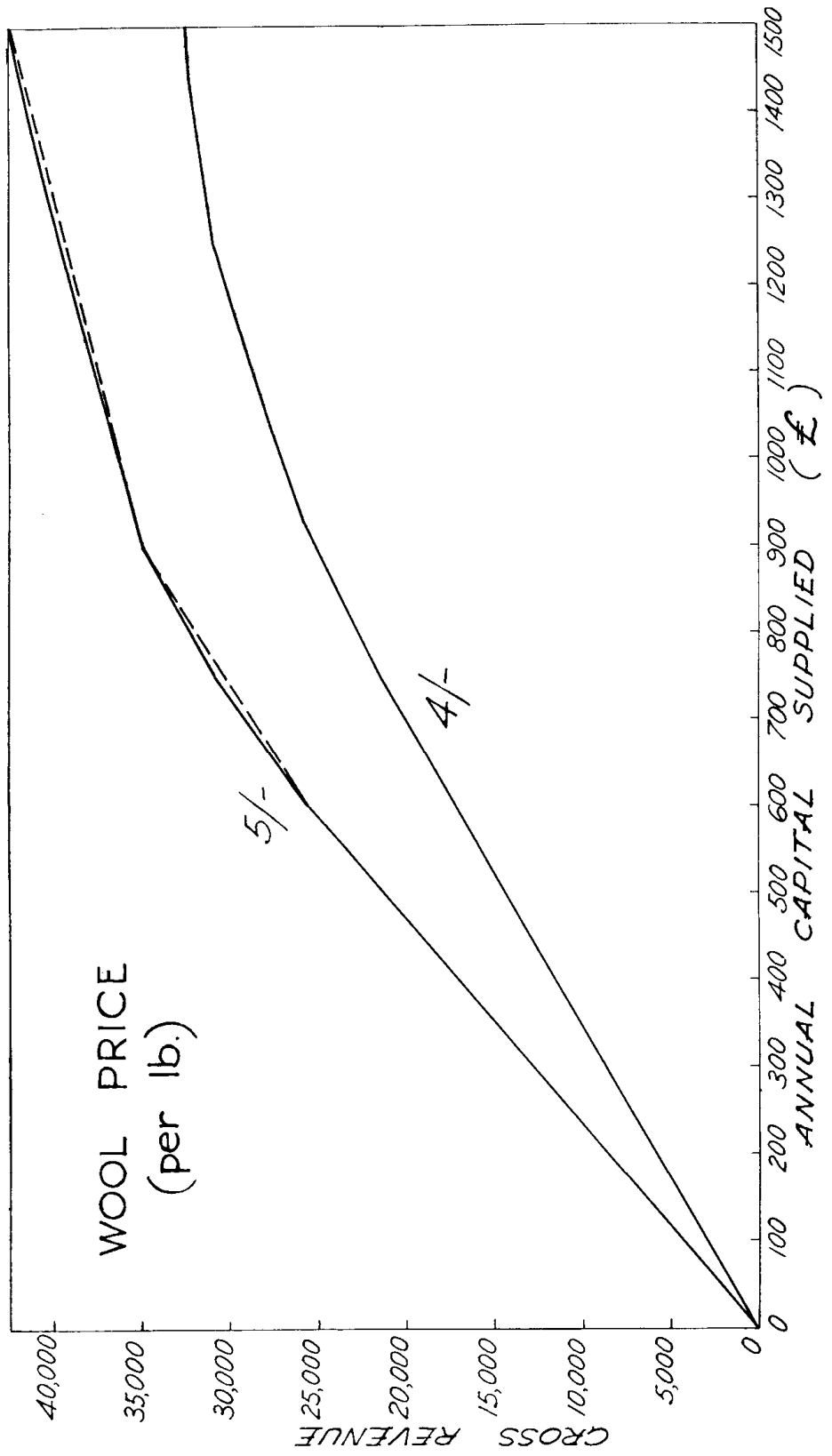


Fig. 2.—Total Revenue Over 20 Years For Sowing Plans, Annual Savings £0 to £1,500, Wool 4s. 0d. or 5s. 0d. per lb. Dashed Line —Revenue for Simplified Advisory Plans.

THE 5s. 0d. PER LB. WOOL PRICE SOLUTION

The results are discussed in relation to the points outlined in specifying the problem on pages 171-172. All levels of savings from £0 to £1,525 per annum were examined. This resulted in 45 plans or forty-four levels of capital at which there was a change in either the restraints operating or the activities in the solution after the first optimum plan was derived. In Figure 1 the results are presented graphically and in Figure 2 is shown the response of the cumulative net profit as the yearly investment is altered. In interpreting Figure 2 it is important to note that for the low amounts of investment, the investment must be carried for more than 12 years and that at higher levels of investment the programme becomes self financing after eight years (see Table 12 for details). In Table 12 some of the plans are shown giving the exact acreages, and some extra information not available on the two figures is included.

TABLE 12

Some Optimum Plans for Varying Levels of Annual Savings—Wool Price 5s.; No Clearing Costs

	Plan Number					
	1	7	17	24	25	40
Net Revenue £ ..	15,259	25,150	30,909	35,505	35,961	41,454
£ Savings	354	586	768	942	968	1,390
Capital not limiting (years)	8, 9	8, 9, 11	5, 7, 8, 9	1, 8, 9, 11, 12	1, 9, 11, 12	1-4, 9-12
Self Finance Year	..	14	13	12	12	10
	Area Sown (Acres)					
Year 1	64 PSB	109 PSB	138 PSB	150 PSB	150 PSB	200 RC17 50 PSB
2	65 $RC2_8$	98 $RC2_9$	100 $RC2_9$ 17 PSB	85 $RC2_9$ 58 PSB	151 $RC2_9$ 35 PSB	200 $RC2_9$ 7 PSB 61 $RC2_8$
3	..	..	..	..	..	200 $RC3_{10}$
4	..	..	..	..	..	27 $RC4_{11}$
5	8 PSB 60 $RC5_{12}$	136 $RC5_{12}$	190 $RC5_{11}$	200 $RC5_{11}$ 89 $RC5_{12}$	200 $RC5_{11}$ 31 $RC5_{12}$	..
6	31 PSB	104 $RC6_{12}$	155 $RC6_{12}$	140 $RC6_{12}$	166 $RC6_{12}$	52 PSB
7	..	23 PSB	..	42 PSB	42 PSB	98 PSB 200 $RC1_7$
8	65 $RC2_8$	..	..	..	41 PSB	61 $RC2_8$ 104 PSB
9	..	98 $RC2_9$ 28 ATD	100 $RC2_9$ 250 ATD	86 PSB 85 $RC2_9$	36 PSB 151 $RC2_9$	200 $RC2_9$
10	164 COM 226 ATD	500 ATD	150 PSB	150 PSB	150 PSB	200 $RC3_{10}$
11	..	..	190 $RC5_{11}$	200 $RC5_{11}$	200 $RC5_{11}$	27 $RC4_{11}$
Time to Sow* ..	?	10 years	10 years	10 years	10 years	8 years

* See text, p. 198. The question mark under Plan 1 indicates that this time has not been calculated and is not known.

(i) *The Effects of Varying the Capital Available*

Figure 1 shows that £586 (as well as returning the income generated) must be invested annually before it is most profitable, under the stated assumptions, to wholly improve a 1,000 acre property in 10 years. This results in an addition of £25,150 to net revenue over a 20-year period.

A grazier who has 1,000 acres of unimproved pasture as his main source of income would be unlikely to be able to save even £200 p.a. (The capital was allowed to rise to £1,500 p.a. to allow for businessmen who wished to invest.) Such a person would have less than one-third of his property improved in ten years. This situation lays crucial stress on the amount of capital required for pasture improvement. It shows that to depend on savings will generally result in a long, slow haul to full improvement. This would be accentuated if a low income farmer, seeing his cash income rising, diverted some of the proceeds to better living rather than to further development.

The amount of capital available also has a considerable effect on the time before the programme is self financing, that is before annual receipts exceed both running and capital expenses. This has already been discussed in regard to a single activity—see Table 7. At a savings level of £586 p.a. it is only in the fourteenth year that annual receipts exceed outgoings. Once investment reaches about £880 receipts exceed outgoings, in the twelfth year, after about £1,030 in the eleventh year, and after about £1,345 in the tenth.

Another aspect of this problem is that of the years in which capital is limiting. This is shown in Table 12, except it should be noted that it has been assumed capital is not limiting in year 2 and year 3. For plan 1 it is limiting in all years but year 8 and year 9. The savings of these years are required later so this has little effect unless, in one of these years income was lower than expected but was made up for by a better than anticipated year by year 10. Therefore to have capital in excess, before the period when the programme becomes self-financing is of little value unless:—

(*a*) The capital could be used up for some other purpose which would repay it by the time it is needed.

(*b*) Savings are lower than assumed due to poor prices, drought, etc. so that even though less capital is available than was expected the plan is not altered provided the missing funds have been replaced by the time capital is again limiting.

The level of savings also affects the time required to sow down the whole property. This is longer than ten years for any level of expenditure less than £586, ten years for expenditures from £586 to £1,154, nine years for expenditure between £1,155 and £1,323 and eight years for expenditures between £1,324 and £1,525 p.a.

Another problem is that of the extent of changes in the relative proportions sown to each activity for a small change in the capital supply. Generally speaking the changes are slow but one contrary example is that of plans 24 and 25, Table 12. We note that despite the quite considerable change in the acreage under the various methods there is only a small change in the income. This suggests that possibly quite large changes

from the optimum sowing might have little effect on revenue. This point is developed further in the next section when considering the manner of presentation of the results.

Finally we may consider whether or not the return to capital invested changes with the level of investment. Inspection of Figure 2 suggests there is a marked diminishing return to capital investment. The picture is not quite so simple because the annual investment is continued for many more years at the lower than at the higher levels. The return to capital is not based on expenditure in the first year, which may be suggested by casual inspection of Figure 2, but on the whole capital invested, irrespective of whether the source is savings or ploughing back the net returns from the programme. This raises the problem of considering the return to capital when both capital expenditures and returns are spread over many years.

One method is to find that discount rate which, applied to the flow of receipts and expenditures will give a sum of zero.[24] Using this technique the interest rate is 9.5 per cent with investment at £586 p.a., 12.1 per cent at £1,016 p.a. and 12.9 per cent at £1,525 p.a., which indicates increasing rather than diminishing returns to capital. The reason for this is that the period when receipts exceed outgoings comes very much sooner which has great weight when a large discount factor is used. In other words the benefits of increasing income quickly are greater than the disadvantage of heavy outgoings whilst the discount factor is still high, which suggests that for those who have adequate capital it would be most profitable to spend heavily for a few years rather than to spread the development over a longer period.

To sum up this part of the discussion, the main feature that emerges is the considerable amount of capital required to develop a property in the relatively long period of ten years. It appears that many farmers and graziers,[25] if they are to be dependent on savings to finance pasture improvement, will face many years of payments exceeding receipts and with no financial benefit in the form of extra cash for private or family commitments. We are assuming that the pasture is fully utilized by adding extra facilities such as watering points, fences, yards and sheds.

This raises the question—is pasture improvement a desirable investment? There is no doubt that it is on a national basis—see for instance, Waring and Jackson.[26] The grazier who has to live through a long period of increasing work and commitments for little immediate benefit may not be so sure. However three points may be made, *firstly*, that on a small property pasture improvement or the purchase of land may be the only way in which a grazier can substantially increase his income. The cost price squeeze will eventually require either an income increase or forced retirement and land purchase like pasture improvement, commits one to a long period of fixed repayments. *Secondly*, that by using loans one may

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[24] Gruen and Pearse, *op. cit.*, $0 = \frac{a_1}{1+r} + \frac{a_2}{(1+r)^2} + \cdots \frac{a_{20}}{(1+r)^{20}}$ where r is the discount rate and a is the gross income less both capital and maintenance expenditure in the year denoted by the subscript.

[25] That is those on small properties and no outside income.

[26] E. J. Waring and J. R. Jackson, "Property Development in New England", this *Review*, vol. 31, No. 3 (September, 1963).

develop the property much more rapidly. *Thirdly,* that income tax may have some substantial effects in reducing the amount of capital required for any given level of improvement.

(ii) *The Methods of Pasture Establishment Selected*

One of the major reasons for undertaking this study was that it had been shown[27] that ATD gave very profitable returns, which raised the questions of whether this technique is economically superior to a method such as PSB which on technical grounds should result in far better establishment and what methods a grazier should use having regard to both technical and economic criteria. We find by inspecting Figure 1 that at some stage each of the four methods considered enters the solution. Therefore glib suggestions to use only PSB as the machinery is available and the ground cleared or to use only ATD because it is rapid and requires little labour are both wrong. No such hard and fast rule can be made. The results indicate that to make the best use of capital, having regard to the sowing limitations proposed, both capital intensive and extensive methods are required. It suggests, too, that one's suspicions that many farmers use too many methods of establishment may be wrong, and they may have found combinations approaching the optimum.

We find that PSB1 enters into all the solutions. This no doubt reflects its great earning powers as well as its ability to provide finance for further development relatively quickly. PSB2 does not enter until considerable capital is available and even then enters at relatively low levels. PSB3 does not enter the solution at any stage and PSB4 was excluded. The remaining PSB activities enter at some stage or another. When capital is very limiting the RC combinations seem important in the middle stages and the later years are taken up largely by ATD and COM. ATD10 provides for half the sowing where capital first permits establishment of the whole property. As finance becomes available ATD10 is first replaced by ATD9 and COM10 which are in turn replaced by PSB or RC combinations. ATD10 is at its maximum from £451 to £592 per annum. In that range $RC6_{12}$ increases from 2 to 188 acres, and $RC3_{10}$ from 17 to 91 acres, showing that increasing finance may permit earlier sowings without affecting a later sowing.

Increase in capital also reduces the time lag between sowings. These are quite long with limited capital but reduce to regular yearly sowings if capital is unlimited. Table 10 shows that plan 40 has sowings in all years other than year 5. In presenting these results to graziers it has been found that they do not object to this spasmodic sowing[28]. Nor were there any objections to following plans of the nature suggested. Their doubts were whether their coefficients would be the same and of how one would adapt to changes in prices or the amount of savings available, rather than of objection to the results as such. Many did not have machinery and they considered that ATD was more desirable than buying machinery to use PSB in the first year. It is likely that this view would be correct.

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[27] Gruen and Pearse, *op. cit.*

[28] Campbell and Shand, *op. cit.*, Table I, p. 28, shows some people sowed at regular, and others at irregular intervals. There were also quite large variations in the areas sown in different years.

(iii) *Sensitivity of the Plans to Changes in Capital Availability*

It has already been noted that 44 changes in plan occurred after the first solution. The first plan was optimum from £0 to £354 which was the greatest range of investment with no change in plan and contrasts with the six changes which occur between £586 and £601, for example.

Generally the rate of increase or decrease of the acreage to be sown to an activity was little affected by a change in plan. The rate of change can be seen in Figure 1, where the greater the slope, the more rapid the change. A rapid change did occur in one instance, that of plan 24 and plan 25—see Table 12. Here an increase in capital of £26 causes a + 66 acres change in $RC2_9$, a − 23 acre change in PSB2, a 58 acre change in $RC5_{12}$, + 26 acre in $RC6_{12}$, − 50 acre in PSB9 and the introduction of 42 acres of PSB9 whilst no changes occur in PSB1, $RC5_{11}$, PSB7, and PSB10. As there is no marked change in income despite these large changes it could perhaps be assumed that there are a great many possible combinations ot sowings which would produce about the same level of net income.

This brings us close to another problem, the complexity of presenting the considerable data which are derived from parametric programming. It would be of great benefit if we could find fewer plans than 45 if this did not greatly reduce the income possibilities. Examination of Figure 2 suggests one way in which this can be done. The income graph for wool at 5s. 0d. shows three points at which there is a considerable change in slope, but between these points the slope is almost constant. Dotted lines have been drawn to emphasize this. Examination of the graph reveals that the greatest loss if one were on the dotted, rather than the solid, line would be £400 in £40,000 or a one per cent difference between the optimum and the dotted line income. Generally the difference is much less. In view of the possible errors in estimating the coefficients one would not expect an order of accuracy of one per cent in the results. Therefore it appears that, practically, there would be little loss involved in using the simple, rather than the complex, solution for advisory work.

As linearity is a property of linear programming a straight line drawn on the representation of an activity in Figure I from one level of capital to any other, would be a feasible solution. At the beginning and end of the line the solution is optimum and in between these points it is sub-optimum. In this case if we choose as points the place where the revenue curve has a marked kink we can reduce the extent of our loss quite markedly. The dotted lines of Figures 1 and 2 show the feasible plans and income which result from reducing the number of plans from 54 to four. Clearly if points other than those at which the kinks occur had been selected the loss in revenue as compared with the optimum would be greater.

Inspection of the 4s. 0d. revenue line of Figure 2 shows that it does not have such pronounced kinks as does the 5s. 0d. line. Thus to avoid too great a loss in revenue with wool at 4s. 0d. per lb. it is necessary to use six plans, which is a considerable simplification from the original forty plans. Inspection of the revenue graph would seem to give a most useful indication as to how best to select points (levels of capital) which could be used in simplifying the plan. Considerable experience suggests that it is possible without much loss to reduce the plans to six or less, which greatly facilitates the presentation of results to a lay audience, either in graphical or tabular form. However it is important to remember that there

are plans other than the simplified one and in the event that a grazier does not like a specific programme it may well be possible, using the detailed original data, to find one more to his liking.

A further advantage which may result is that the number of activities is reduced. Where an activity enters and never reaches a level of more than five or ten acres it would often be impractical to consider it. Judicious selection of the points may result in the removal of such activities. In the example of Figure 1 the number of activities considered is reduced from 19 to 15.

(iv) *The Marginal Value Products of the Limiting Resources*

The limiting resources change as capital is increased. In the first plan only capital is limiting but by the final plan there are eight yearly sowing restraints and only three capital restraints effective. The details of the marginal value products for the plans shown in Table 12 are outlined in Table 13. Thus we see for Plan 1 that an extra £1 of capital in year 1 would add £2.159 to the revenue. This theoretically represents a return to capital of 216 per cent which is extremely high. However several points should be kept in mind whilst considering these figures.

TABLE 13

The Marginal Value Product of the Limiting Restraints for Selected Plans, Wool 5s. per lb.

	Plan Number					
	1	7	17	24	25	40
	£	£	£	£	£	£
Net Revenue	15,259	25,150	30,909	35,505	35,961	41,454
Annual Savings ..	354	586	768	942	968	1,390
Capital—Year 1 ..	2·16	2·21	1·75	..	..	..
Year 4 ..	1·42	1·28	1·25	·69	·71	..
Year 5 ..	·36	·06	..	·06	·08	1·16
Year 6 ..	1·05	1·23	·7	·462	·41	·08
Year 7 ..	·2	·28	..	·62	·52	0
Year 8 ..	..	..	..	0	·14	·54
Year 10 ..	·24	·64	1·75	·78	·69	..
Year 11 ..	·06	..	..	..	..	..
Year 12 ..	1·9	1·5	·2	..	..	..
Property size	..	0	6·84	17·28	17·83	24·93
Sowing—Year 1 ..	..	..	9·2	7·14	6·93	4·9
Restraint—Year 2 ..	..	..	..	..	..	..
Year 5 ..	..	..	..	..	..	..
Year 6 ..	..	..	·69	..	..	2·68
Year 7 ..	..	..	..	..	..	·76
Year 8 ..	..	..	..	..	..	1·19
Year 9 ..	..	..	·62	·78	1·06	1·44
Year 10 ..	0	6·14	2·22	·17	·10	·53
Year 11 ..	..	..	..	·36	·36	..

First, that the revenue is the sum of undiscounted returns over a 20-year period. Calculated on a present value basis the return would be much lower. The present value of £1 p.a. for 20 years at 10 per cent is £8.515. Therefore if the income was spread evenly over the years the present value would be about £92 or a return of 92 per cent. As there is little income flow in the early years and a greater flow later, the present value would be much lower than £92. So the "real" return to capital is lower than the figures of Tables 13 and 15 suggest.

Secondly, that if one still considers the returns to be unduly high we must consider that these funds come purely from savings, that it was assumed there was no possibility of borrowing. Therefore these returns may to some extent measure the sacrifice attached to not borrowing money for pasture improvement.

TABLE 14

Some Optimum Plans for Varying Levels of Annual Savings—Wool Price 4s. per lb. No Clearing Costs

	Plan Number						
	1	6	13	22	28	39	40
Net Revenue ..	£ 11,598	£ 24,084	£ 27,348	£ 28,370	£ 30,752	£ 32,349	£ 32,893
Savings	400	835	985	1,050	1,257	1,452	1,541
	Area Sown (Acres)						
Year 1	72 PSB	150 PSB	150 PSB	150 PSB	150 PSB	76 PSB 49 $RC1_7$ 99 $RC1_8$	30 PSB 39 $RC1_7$ 200 $RC1_8$
2	43 PSB	89 PSB	127 PSB	81 PSB 92 $RC2_8$ 46 $RC2_9$	38 PSB 134 $RC2_8$ 88 $RC2_9$	74 PSB 152 $RC2_9$	94 PSB 113 $RC2_9$
3	..	..	..	23 $RC3_{10}$	200 $RC3_{10}$ 9 PSB	126 PSB 47 $RC3_9$	106 PSB 87 $RC3_9$
4	..	..	19 $RC4_{11}$	..	..	39 $RC4_{10}$	101 $RC4_{10}$
5	31 $RC5_{12}$	273 $RC5_{12}$	181 $RC5_{11}$ 119 $RC5_{12}$	200 $RC5_{11}$	52 $RC5_{11}$	..	..
6	31 PSB	7 PSB	67 PSB	87 PSB	44 PSB	148 PSB 49 $RC1_7$	108 PSB 39 $RC1_7$
7	..	..	..	76 PSB	150 PSB	113 PSB	120 PSB
8	29 COM	300 COM	43 COM	92 $RC2_8$	134 $RC2_8$ 49 PSB	99 $RC1_8$ 76 PSB	200 $RC1_8$
9	..	26 PSB	150 PSB	116 PSB 46 $RC2_9$	84 PSB 88 $RC2_9$	47 $RC3_9$	87 $RC3_9$
10	150 PSB	150 PSB	150 PSB	133 PSB 23 $RC3_{10}$	.. 200 $RC3_{10}$	39 $RC4_{10}$	101 $RC4_{10}$
11	..	..	181 $RC5_{11}$	200 $RC5_{11}$	52 $RC5_{11}$	..	..
Time to Sow* ..	?	?	10 years	10 years	9 years	8 years	7 years
Year—Capital not Limiting	7, 9, 11	6-9, 12	1, 7-9, 11, 12	1, 7, 11, 12	1, 6, 10-12	1, 9-12	1, 8-12
Self-finance Year ..	..	..	12	12	11	10	10

* See text, p. 204.

Thirdly, that it is unlikely that capital will be spent in quite so rigid a pattern as we assumed in the programme. If returns to one year are much higher than in other years, in practice it may be possible to delay expenditure on say fences, yards or buildings for a year or two, without greatly reducing returns. This would substantially reduce the marginal productivity of capital in that year. Therefore these values may be used as approximate guides to the period when capital will be more or less restrictive rather than used in a strict economic sense.

For the early plans land is not limiting and so has no marginal product. When it does become limiting its marginal value rises steadily to a peak of £27.8. In view of the previous comments this might represent a present value of about £12 which appears rather low. Naturally there are costs associated with the yearly sowing limit, though these are not especially high except for that of the first year. This would increase revenue by £9.2 per acre (plan 17) which is greater than the £6.84 of an extra acre added to the property. This value diminishes as the area sown in the early years increases. As farmers and graziers will occasionally sow a much greater than average area these marginal value products would provide a useful guide in selecting years where the practice would give a considerable boost to income. If the marginal value were zero or low it would indicate that there might be little to gain by accepting the risk of a large sowing.

The 4s. 0d. Wool Price Solution

The activities selected for inclusion in this matrix were PSB1–3, 5–10; COM1–5, 7, 8; ATD1, 2, 10; and $RC1_8$–5_{12}, 1_7–5_{11}. Of these all the PSB and RC activities and COM 8 entered one or other of the 40 parametric solutions. In no case did an ATD activity enter the solution. Due to space limitations it is not possible to present the 4s. 0d. data graphically. Instead the results for selected plans are presented in Table 14. These plans were selected mainly by inspection of the revenue graph, Figure 2. Note that there are more turning points than is the case for the 5s. 0d. solution, giving five plans compared with four. Inspection of the data shows much the same pattern as was observed in the 5s. 0d. case, except that there is no extensive aerial sowing in the low capital stages.

(i) *The Effects of Varying the Capital Available*

To fully improve the property in 10 years the capital requirement rose from £586 to £836, although the number of solutions fell from seven to six. The first plan is optimum up to £400 per annum, allowing an improvement of 456 acres. Assuming maximum savings of £200 on an unimproved 1,000 acres property with no outside resources, then only 228 acres, or less than a quarter would be improved in ten years.

The time taken for the whole property to be sown for levels of savings below £985 is unknown. For levels of savings from £985 to £1,220 it is 10 years, between £1,221 and £1,362, 9 years and between £1,363 and £1,541, 8 years.

The internal rate of return to capital is 8.5 per cent at the £836 expenditure level, 10 per cent at the £1,220, and 10.4 per cent at the £1,541. If 10 per cent is the minimum return at which one would recommend beginning such an inherently risky thing as pasture improvement it is clear that

at the likely levels of savings these returns are inadequate. Nevertheless if one considers the carrying capacity to be conservative and the Northern Tablelands to be a "safe" climatic zone with little chance of pasture failure, then these returns may be acceptable. A pessimistic or optimistic view of the course of future costs and returns as well as views on off farm investment would all be important in making a decision.

The amount invested before capital ceases to be limiting in various years is shown for the 4s. 0d. wool price, with the 5s. 0d. wool price figure in brackets. Although capital may not be limiting this need not mean that we could do without that year's contribution, e.g., year 12 is not limiting after the supply of £719 per annum but is not self financing in year 12 until an annual investment of £970. Capital ceases to be limiting in year 12 after £719 (£823), in year 11 after £935 (£823), in year 10 after £1,089 (£1,131), in year 9 after £1,286 (£1,324) and in year 8 after a supply of £1,452 (£1,425) per annum.

We see that generally capital ceases to be limiting at a lower rate of annual savings for the 4s. 0d. than 5s. 0d. price. Possible explanations are first, the greater preponderance of PSB in the solutions with its early returns, or secondly, the lower capital cost of sheep, which in the case of PSB and COM, means the greatest debt is less than for the 5s. 0d. wool price—see Table 7. Despite this the effect of the lower returns of the 4s. 0d. wool price show the amount of capital required before a given year is self financing. Taken in the order above, year 12 at £970 (£890), year 11 at £1,140 (£1,030) and year 10 at a capital supply of £1,350 (£1,340) per annum. Another effect of the lower price is that it takes longer before total receipts equal total expenses—see Table 7.

There were occasions of frequent changes in plan for a small difference in annual capital supply, e.g., eleven changes of plan between £956 and £1,050, compared with no change from £0 to £400. There were no very rapid changes between plans as occurred between plan 24 and plan 25 at the 5s. 0d. wool price.

To summarize, the changes that occurred as the capital supply was varied were similar to those at the 5s. 0d. wool price. At low supplies of capital the return is only about 8½ per cent which does not appear very large compared with the risk and uncertainty associated with pasture improvement. The emphasis is again on the substantial amount of capital required and the long period which elapses before the programme is self financing.

(ii) *The Methods of Pasture Improvement Selected and the Marginal Value Products*

At the lower wool price the emphasis is on PSB and RC which give returns quickly or are partly self financing. The most extensive technique, ATD, did not appear and there was no COM except in year 8 when at some finance levels the maximum area permitted came into the solution. It would seem that at low wool prices the returns take so long to eventuate that they are unable to compete with those methods which, whilst more expensive, give much more rapid returns. The greatest interval between sowings is two years. As before, the extent to which sowings are spasmodic rather than regular is a function of the capital available. The marginal

value products of the restraints are shown in Table 15. The results are similar to those at the 5s. 0d. wool price except that the values are lower and the value of the first year sowing restraint rises whereas before it declined.

TABLE 15

The Marginal Value Products of the Limiting Restraints for Selected Plans
Wool 4s. per lb.

	Plan Number						
	1	6	13	22	28	39	40
	£	£	£	£	£	£	£
Net Revenue	11,598	24,085	27,348	28,370	30,732	32,350	32,893
Annual Savings	400	836	985	1,050	1,257	1,452	1,541
Capital—Year 1	1·19	1·12	..	..	..	..	..
4	·75	·21	·26	·42	·34	·07	·02
5	·78	1·27	·74	·45	·36	·08	·02
6	·1	..	·38	·16	..	·19	·26
7	..	..	..	..	·14	·55	·62
8	..	..	..	·36	·52	·11	0
9	..	..	..	·25	·18	..	..
10	1·25	1·45	1·28	·26	..	..	..
11	..	·43	..	..	..	..	..
12	·65	..	..	..	..	..	..
Property Size	..	0	6·51	14·4	16·75	20·15	20·64
Sowing—Year 1	..	..	5·33	4·13	5·52	8·69	9·36
Restraint—Year 2	..	..	..	·23	1·96	5·0	5·61
3	..	..	..	..	..	2·09	2·5
5	..	..	·05	..	..	..	..
7	..	..	..	..	·14	·52	·62
8	..	..	..	..	·58	1·00	1·14
9	..	..	·9	·68	1·06	·33	·16
10	0	3·92	2·2	0	·97	..	..
11	..	..	·33	..	..	..	..

6. CONCLUSION AND SUMMARY

In this paper it has been suggested that there is a problem of selecting the methods by which a property should be pasture improved. It was postulated that basically four methods are feasible, namely a fully prepared seed bed (PSB), combining into an existing native pasture (COM), aerial spreading of seed and fertilizer (ATD), and combining later ripped up and resown as a roughly prepared seed bed (RC). Estimates were made of the year by year stock carrying capacities and capital and variable expenses for each method. The estimates were used in a linear programming matrix to map the optimum pasture improvement programme for a 1,000-acre property as the capital available for the programme varied from zero to about £1,500 per annum. Wool prices were held constant for 20 years at either 4s. 0d. or 5s. 0d. per lb. Sowing by the various methods was permitted in any of the first 10 years. Capital was assumed to be available from annual savings resulting from the existing operation of the property, and by reinvesting the profits resulting from the improvement programme. A number of general conclusions can be drawn from the study.

First, with a wool price of 5s. 0d. per lb. the returns are about 10 per cent or better. At the level of finance one would expect to be available the returns for a wool price of 4s. 0d. are a little over 8 per cent. Due to uncertainties such as climate, prices, and management and to the considerable period before the schemes become self financing this apparently

small difference may be of great importance marginally in deciding between on farm and secure off farm investments. The returns in any case are greater than those which can be obained in secure investments but they are distant returns. As conservative figures have been used throughout it can be said that pasture improvement pays, with some reservations which would depend on the individual grazier's position, at the lower price. However, it is true that large capital sums are required. If these are not available, pasture improvement from savings will be a long, discouraging task, with the time before receipts exceed outgoings being far distant. Even if large sums are available it is some time before receipts exceed outgoings.

Secondly, it appears that no one method of pasture establishment is optimum but that all the methods considered had a place at some stage of development, depending on the amount of money available. This suggests that technical criteria, which would have us select prepared seed bed, will not necessarily result in the greatest return per unit of capital. In fact due to the posulated restriction of 15 per cent of the property as the maximum one could plough in any year, even if money was unlimited, prepared seed bed alone would not give the greatest return over the 20 year period studied. The fact that any method of improvement may be selected suggests that the many varied methods of establishment met in the field may be rational. Certainly where there are substantial capital limitations small and spasmodic sowings may well be the optimum way of improving.

Thirdly, there may be substantial changes in the optimum development plans if wool prices alter. This is also partly affected by the amount of capital available. As capital increases the optimum plans become closer. No data was presented to show the effect of year to year fluctuations in wool prices, only the difference if wool was constant at either 4s. 0d. or 5s. 0d. per lb. for the 20 years.

Fourthly, that whilst a parametric linear programme provides a vast flood of data, indicating changes in methods and area of establishment for fairly small changes in capital availability, it is possible to substantially reduce the complexity with little loss of revenue. In the examples quoted a solution with 44 optimal plans could be easily simplified to four, and one of 40 plans to five, with a loss of one per cent or less in net income. This is done for convenience of presentation for extension work. The multiple solutions may still give insight into an individual problem and so they should not be discarded or forgotten.

Fifthly, these results suggest that linear programming can supply worthwhile insights into the pattern of expenditure for pasture improvement development plans. This information should be of great value to extension workers. An important contribution could be made by establishing critical coefficients such as the carrying capacity of different methods of pasture establishment in various regions and using this data to obtain development patterns for a range of conditions. Should extensive methods such as aerial broadcasting give little response once annual rainfall falls below 25 in. it may be that results such as those presented above would have very limited application. Alternatively one could use variable coefficient techniques to establish the extent to which coefficients could change without altering the general pattern of these results.

Finally, the marginal products of the limiting resources, whilst subject to considerable qualification, provide invaluable practical information for adding the flexibility present in real life situations. Thus one could make changes in the timing of capital expenditures or relaxation of the rigid rule about the extent of sowing in a given year (too great a change would nullify the results presented which are what they are by virtue of these restraints). One way of introducing flexibility would be the use of short term credit in a year where capital in one year has a high marginal product but a low one in the following year.

It has been shown that under the conditions specified all methods of pasture improvement may have a place in selecting an economic development plan, that pasture improvement is a paying proposition, and that both wool price and capital availability considerably affect the optimum sowing combination.