FARM PLANNING IN THE GRAMAN DISTRICT OF NEW SOUTH WALES

A LINEAR PROGRAMMING STUDY OF ADJUSTMENT POSSIBILITIES FOR SOME SOLDIER SETTLEMENT FARMS

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1. INTRODUCTION

A survey of twenty-three soldier settlers who face adjustment problems following falls in sheep product prices and damage to pastures by a scarab pest is reported. Settlers estimates of input-output coefficients, and results from agronomic experiments, were used in formulating production possibilities in linear programming matrices. Normative plans for farm organization, to maximise incomes over a range of relative prices of agricultural and livestock products, were derived from these matrices by simplex programming.

It was deduced that settlers could increase incomes by devoting all arable or potentially arable land to a cash crop rotation, even where pastures are not scarab infested. Once embarked on such a programme, substantial change in relative prices would be required before further adjustment was merited. Improved rotations for the district have been suggested by co-ordinating results from programming and agronomic experiments.

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Some of the settlers have examined the plans and consider them applicable in their own farm situation, and it is believed that the plans may provide benchmarks for extension and research workers serving the area.

A recent review by Swanson[1] suggests that few pragmatic studies of farm situations using linear programming to guide technological research and extension have been completed or found acceptance in the U.S.A., although the derivation of optimal "benchmark plans" can greatly increase understanding by "articulation of the relationships among the variables" in the farm situation. Some pitfalls in such planning are discussed by Edwards[2] and Waugh[3]. The latter discussant pinpoints accuracy of input-output data and deficiencies of static economic theory as the most important of such pitfalls, but concludes: "even the simplest linear programming techniques can be useful if used with discretion and judgment".

Our current experience tends to support Waugh's conclusion. In the present study the extent of suggested adjustment is such (involving in some cases a more than doubling of expected net revenue) that even informed guesses of the magnitudes of input-output coefficients can assist in understanding and quantifying the relationships among variables in a moderately complex situation.

The project is to some extent notable as an example of a "systematic program of data gathering in which both economists and technologists participated", as advocated by Hildreth[4]. Already we can report "practical application", using Swanson's criterion, by one farmer outside the survey group. Whether "commercial adoption" will be followed by commercial success remains to be seen.

In one of few Australian studies of this nature, Parker[5] surveyed 108 farms in the Kojonup district, Western Australia, finding many farms organized at apparently substantially suboptimal levels. He comments on the potential problem of inducing farmers to identify their farms with the production possibilities suggested by programming, a matter on which Swanson makes further comment. It has been our experience that an answer provided by Swanson has applied in this case.

The settlers were invited to participate in proposing the questions to be investigated in the study. They recognized the existence of an adjustment problem and the solution offered is one that is palatable because it recognizes restraints on development, identified by them in the course of the survey. At the completion of the project all farmers could not be visited to invite comment on the plans computed, but three whose

[1] E. R. Swanson, "Programmed Solutions to Practical Farm Problems", *Journal of Farm Economics,* Vol. XLIII, No. 2 (May, 1961), pp. 386-392.

[2] C. Edwards, "Shortcomings in Programmed Solutions to Practical Farm Problems", *Journal of Farm Economics,* Vol. XLIII, No. 2 (May, 1961), pp. 393-400.

[3] F. V. Waugh, Discussion of Swanson and Edwards papers, *ibid,* pp. 404, 405.

[4] C. G. Hildreth, "Some Problems and Possibilities of Farm Programming", *Fertilizer Innovations and Resource Use* (Ames: Iowa State College Press, 1956).

[5] M. L. Parker, "Programming for Farm Management Extension", *Journal of the Australian Institute of Agricultural Science,* Vol. 25, No. 4 (December, 1959), pp. 267-272.

current farm organization had several of the features found in the plans were re-interviewed. Each expressed conviction that his farm organization could be adapted with advantage to incorporate new features derived from the survey results.

In a previous study[6] the senior author quantified coefficients in a 24 x 26 matrix in co-operation with an experienced farmer who described production possibilities for his farm, enterprise by enterprise, and identified the restraints on his own production. When solved by simplex programming, the optimum product mix resulting closely resembled that produced by the co-operating farmer. A plan for further development was described and later followed in practice.

In that study, as in earlier studies by Parker [7] and McPherson and Faris,[8] it was shown that a particular "near" solution to the allocation problem may be relatively insensitive to price, resource, and coefficient changes.

In the current project, modal estimates of input-output coefficients from all respondents in a group of twenty-three farmers have been used in defining production possibilities and to derive "benchmark plans". Parametric programming has been used to compute plans applicable to the range of farm situations encountered in respect of arable land supply, and the sensitivity of the plans to inaccurary in key parameters of the matrices can be deduced from marginal costs of disposal of limiting resources. In general, the applicability of the solutions on farms whose input-output coefficients differ from the mode can be deduced in the same way. Once again, in this study, the "benchmarks" in adjustment appear comparatively immoveable in the face of substantial variation in prices and coefficients.

Farmers' expected input-output coefficients are presumably used as a basis in their planning. They were compared between survey farms and with the experience of farmers and research workers outside the sample, revealing reasonable consistency and plausibility. Parametric programming provides an inexpensive, rapid, and highly informative means of assessing the likely effect of errors of estimation—which in the current situation appears unlikely to affect the conclusions reached. Accordingly we believe that the prospects for success in similar extension-directed investigations are favourable.

As a matter of interest, during this project approximately eight man days were spent on field surveys and forty minutes computer time on the digital computer SILLIAC maintained by the University of Sydney was used. This excludes office time which was much larger, but might be expected to be less on future similar projects.

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[6] E. J. Waring, *Linear Programming Using Farmer-Estimated Input-Output Cofficients* (M.Agr.Ec. Thesis, Armidale: The University of New England, February, 1962 (mimeo)).

[7] *op. cit.*

[8] W. W. McPherson and J. E. Faris, " 'Price Mapping' of Optimum Changes in Enterprises", *Journal of Farm Economics,* Vol. XL, No. 4 (November, 1958).

2. THE SURVEY FARMS

Gragin Closer Settlement Estate and "Ulupna", a smaller estate, lie between the townships of Delungra and Graman, slightly west of Inverell. The majority of the original settlers entered into occupancy of their blocks towards the end of 1947. Some blocks were designed for fat lamb production, others were to be fat lamb blocks with sideline cropping to wheat, while only two blocks were designed as predominantly wheat blocks. The mean size of the twenty-three blocks visited was 1,226 acres, ranging from 815 to 1,576 acres according to the use for which designed.

The principal soil type is a heavy black soil derived from basalt, often with substantial amounts of surface stone. The blocks are characteristically undulating and subject to considerable erosion hazard when cultivated. On many of the blocks, cropping was made conditional on the construction of appropriate mechanical protection against erosion.

There are smaller areas of an older less fertile red soil, derived also from basalt, and isolated light sandy patches carrying Cypress pine (*Calitris* sp.). The average annual rainfall at Graman is about 27 inches. The black soil scarab (*Othnonius batesii*) is widespread throughout the two settlements, associated with infestations of mintweed (*Salvia reflexa*) where the grass cover has been severely, and selectively, denuded by the depredations of this pest.

The original grass cover was of two types: (1) Predominantly white top (*Danthonia linkii*) ; (2) Plains grass areas (*Stipa aristaglumis*).

With the spread of mintweed these better grasses have in many cases disappeared so that spear grass (*aristida* sp.) and red grass (*Bothryochloa biloba*) together with mintweed make up the major components of the native pasture. With good autumn rains substantial amounts of medics (*M. denticulata* and *M. minima*) may be found in these pastures, especially where grasses have been killed out by the scarab and when mintweed is dominant. However, a majority of settlers indicated that, in their experience, this was of infrequent occurrence and might be expected no more often than about once in four years.

These adverse changes in pasture composition, attributed mainly to the depredations of the scarab, have had an adverse effect on output of animal products. It will be seen that opinions regarding the effect of the pest differ, indeed its importance for the Gragin settlers, as a group, may have been overemphasized. However, its presence has undoubtedly exacerbated the adjustment problems posed the settlers by trends in wheat prices, and in sheep prices and costs, over the last ten years. The majority of the settlers had little experience of crop production applicable to the district when they entered into occupation of their blocks.

Currently, a majority of settlers are running merino sheep, endeavouring to breed their own replacements, and, almost without exception, are endeavouring to grow the maximum possible acreage of cash crops, namely, spring (and some winter) wheat, oats, barley for grain, grain sorghum, and small amounts of cowpeas. A number grow significant acreages of lucerne and there have been experimental sowings of *Sorghum almum* and green panic grasses. A few settlers have undertaken pig raising as a sideline.

During the course of the survey reported below we gained the impression that few of the settlers had clearly determined the best ultimate organization for their properties, and most had been hampered in attaining any such organization by lack of an established arable farming pattern for the area, by capital rationing, and by the inevitable delays involved in clearing, fencing, erosion control measures, and related changes necessary in converting from a predominantly grazing to a maximum arable farming pattern.

On the Gragin estate 15 of the 30 blocks have changed hands. One of these has changed hands twice. Some of these have been the more completely arable blocks, and consequently the potentially better revenue producing blocks. At least one of the settlers has purchased an additional area of arable land, one settler interviewed was sharefarming on part of another settler's block.

3. SURVEY AND ANALYTICAL METHODS

Following preliminary discussion at a public meeting of settlers late in 1960, 23 were finally interviewed early in 1961. This represents nearly 70 per cent of the total population of 34 properties. Of the settlers who did not take part in the survey, the majority had been in occupation for very short periods.

To secure maximum co-operation at the first contact, settlers were not asked to supply full financial details of their undertakings. However, most settlers proved quite willing to give any information requested, many stating that even if the investigation provided no information to assist them individually it might conceivably assist others.

The questionnaire concentrated on the collection of input-output data and physical details of crop acreages and stock numbers over a five-year period. In the main, reliance was placed on recollection as few of the settlers kept accurate records except of wool sales and prices. The technique proved reasonably successful for the purposes of a preliminary survey. Although one or two of the settlers had an extremely hazy idea of crop yields, most had well defined expectations of yields and carrying capacities which were relatively constant from farm to farm and which agreed with experience on adjacent properties outside the settlement. Details of numbers of all classes of stock currently depastured were secured, as well as acreages of individual crops. Settlers were also asked whether these figures had changed significantly in recent years or whether future changes were planned, as well as the extent of any such past or proposed changes.

The modal estimates of input-output coefficients were then used in estimating coefficients for a 10 x 9 linear programming matrix incorporating the principal enterprises and restraints indicated by the participating landholders. (See Appendix I, Matrix A.) It was evident that the greatest net return to land was secured from arable cropping and that neither shortage of machinery nor labour was yet an important restraint on increased cash cropping on the majority of farms. The settlers clearly recognized this state of affairs, and all stated that they planned to continue efforts to increase cultivated acreage wherever possible, although progress had generally been slow and some farms lagged behind others.

It was concluded that the objectives of an initial survey would be best met by developing criteria for allocating arable acreage between cash and fodder crops and determining the period of the year[9] at which feed supplied would be most likely to prove limiting within feasible enterprise combinations. Cash cropping ventures so clearly dominated the land use possibilities that it was considered no credible degree of inaccuracy in current yield and price estimates could have a significant effect on criteria for allocating land between arable and non-arable uses. However, the productivity of native pastures was less clearly defined, especially under systems of management including substantially greater provision of feed from lucerne and crop grazing, which are still relatively undeveloped in this district. Such systems would possibly provide opportunities for deferred grazing of native pasture, in contrast to the pattern generally in use, i.e., more or less continual grazing throughout the year.

Accordingly the production patterns, in "dry merino ewe equivalents" (D.M.E.) of feed, of two proposed methods of using native pasture were defined on the basis of the best estimates which could be made and confirmed with the settlers whose current management practices most closely approximated them. Similarly two methods of managing grazing lucerne were specified. The feed requirements of a breeding flock approximating modal composition on the settlement were estimated (again in dry merino ewe equivalents) from data based on feeding experiments and shown to approximate experience under similar soil and climate conditions about forty miles away.[10]

The matrix of production possibilities so derived is shown as Matrix A of Appendix 1. Two additional matrices were derived from Matrix A, varying only in the level of feed output from native pastures which was set in one case 33 per cent below and in the other 50 per cent above the modal estimates. These three matrices were used to compute optimal plans for a 1,000 acre property with any proportion of arable land from zero to 100 per cent, using a quantity—variable linear programming technique. Tables 1, 2 and 3 list the plans at the discrete acreages where returns to limiting resources change in the discrete steps encountered in this method of programming.

The resulting plans indicate the approximate shape of three sets of production possibilities which can be interpreted to show the effect of changing arable land supply if estimates of pasture productivity (or output of sheep products) is equal to, somewhat more, or somewhat less than the estimates which appeared most likely. Alternatively they permit some estimate of the change in farm organization required if net revenue from cash crop is more, or less, than that assumed. The general nature of the plans is comparatively insensitive to such variations in estimates.

The cash crop rotation incorporated in the first set of matrices (i.e., based on matrix A) departs from current practice in requiring that arable land spend five years out of eleven under pasture. This is a more conservative rotation than practised on all but one or two properties at present,

[9] The "year" was divided into four periods of three months, viz.:—Spring—August to October, Summer—November to January, Autumn—February to April, Winter—May to July.

[10] E. J. Waring, *op. cit.*

and results in relatively reduced revenue for a given arable acreage, together with lessened marginal revenue products for feed in the periods of scarcity indicated by programming. However, estimates of the effect of a narrower rotation may be made by inspection of the marginal revenue product of the activity "legume disposal". It may never be necessary to follow quite so conservative a rotation but, if cropping continues, greater use than at present of lucerne or some similar crop will be essential as the black oat problem increases and the initial "fertility" remaining from long periods under native pasture is depleted.

As a result of the investigation it has been possible to "synthesize" a rotation apparently superior to that derived, as above, on the basis of current practice and apparent trends.

4. FARM PLANS DERIVED BY LINEAR PROGRAMMING

The linear programme matrices used are shown in Appendix I and the budgets on which they are based are listed in Appendix II. The initial specification, more closely resembling current appraisal of production possibilities, will be discussed first. Notable features of the three matrices based on current practice are listed below.

(1) The main wheat-barley-oats rotation, which approximates current practice on the farms, requires five years under lucerne for each six years under arable crops.

(2) Grain sorghum has been omitted since this crop appeared to be regarded as a catch crop or chance component of the cropping system—and because of the general difficulty so far experienced in fitting sorghum into the emerging pattern of crop rotation for the settlement.

(3) Provision is made for the sowing of additional oats outside the stipulated rotation, not subject to the fertility-based lucerne constraint, but providing the same yield as oats in rotation. This activity does not enter any of the plans.

(4) Two methods of using lucerne and two alternative methods of using native pasture are included, which approximate current practice on at least some farms of the settlement. We cannot be sure that these represent all possible alternatives, nor that the activities as formulated in matrices A and B are the exact level at which feed will be available from native pasture. The second of these appears the more significant source of possible errors—since any plan can "mix" the two specified alternatives—and accordingly we have solved matrices A and B with pasture coefficients increased by half, and reduced by one third, to show the likely importance of inaccurate estimates in this regard. It is questionable whether inaccuracies of estimation as great as this exist. Most settlers have explored the effects of higher stocking rates with low levels of cropping and been forced to reduce to the observed levels. It would seem that serious under-estimation of pasture productivity is unlikely unless there are unexpected complementary effects between native pasture and fodder crops. Such effects would presumably become most important with higher percentages of arable land than exist on most farms at present, and under such conditions the disparity between stock numbers and expected revenue with differing carrying capacities assumed for native pasture is strongly decreasing.

(5) It is considered that wheat yields at least equal to modal estimates could be secured on most properties. Where wheat yield was low, soil preparation was late, which was related to a shortage of summer feed. Such shortage would be less likely with the rotations suggested.

The Computed Farm Plans—"Current Technology"

The plans appropriate to the three levels of pasture productivity are shown in Tables 1, 2 and 3 which are based on a farm of 1,000 acres. The columns headed by Roman numerals show the plan at points of change of average (and "marginal") revenue products of the various enterprises and constraints in the matrices. The first line in each case refers to the corresponding arable acreage for which the plan is optimal.

It will be noted that the enterprise mix for any intermediate arable acreage is a linear combination of the plans at the point of change above and below. Thus the plan for 250 acres arable, which is shown in Table 4, comprises $\frac{250—119}{(814.5—119)}$ of Plan III (for 814.5 acres arable) together with $\frac{814.5—250}{(814.5—119.0)}$ of Plan II. It will be noted that the marginal revenue products do not change between programme steps and those for plan 250 are the same as for Plan III.

Table 4 shows the computed plans appropriate to arable acreages between 150 and 450 on a 1,000 acre property.

In reading the tables, the following explanatory comments may be of assistance.

In the case of limiting resources, the "opportunity costs" listed measure the reduction in revenue which would result if one unit were removed, and are Z-C's from final matrices. In the case of activities, they define the reduction in income if one acre of an activity in the plan were removed, or an acre of a not-included activity were substituted for those in the 1,000 acre plan, in the least suboptimal way. Where the activity in question is included in the plan they correspond to the Z-C for a restraint limiting that activity to one unit below the computed level.

Thus considering Plan III of Table 1 where a total of 369.4 acres of lucerne to be grazed, partly as Lucerne I and partly as Lucerne II, it might occur that the size of existing paddocks dictated a different apportioning of this crop between the two methods of management. The "opportunity costs" assigned to Lucerne I and Lucerne II permit an assessment of the costs of making the change, and in this particular case have been calculated arithmetically from the appropriate costs on feed disposal in the relevant time periods.

It will be noted that if, for example, an acre of Lucerne II be removed from Plan V, no opportunity cost is incurred. The fact is that substitution of Lucerne II for Lucerne I, or vice versa, has no effect on feed supply in limiting quarters. Thus V is only one of a family of plans producing the same revenue but differing in the proportions of Lucerne I and Lucerne II making up a total of 437.8 acres lucerne. Plans VII and VIII of Table 1 show two such plans differing in oat use.

TABLE 1

Plans Computed from Matrix A—Pasture Coefficient at Observed Mode

	Unit	Plan Number							
		I	II	III	IV	V	VI	VII	VIII
Arable Acres	....	0	119·0	814·5	922·3	965·3	987·6	1000	1000
Enterprises									
Spring Wheat Rotation ..	Acres	0	65·0	445·1	504·0	527·5	539·6	546·4	546·4
Winter Wheat Rotation ..	Acres	0	0	0	0	0	0	0	0
Sheep	Ewes	540·5	537·4	443·9	427·9	391·9	373·3	362·8	362·8
Lucerne I	Acres	0	54.0	92·1	131·2	0	0	0	0
Lucerne II	Acres	0	0	277·3	287·1	437·8	447·9	453·6	453·6
Native Pasture I	Acres	0	0	0	77·7	34·7	12·4	0	0
Native Pasture II	Acres	1000	881·0	185·5	0	0	0	0	0
Oat Use	Acres	0	21·5	146·9	166·3	174·1	155·5	151·2	180·3
Oats	Acres	0	0	0	0	0	0	0	0
Revenue (£)	....	1047·0	1302·6	2651·6	2857·6	2882·5	2895·4	2902·6	2902·6
Surpluses									
Oat Supply	Acres	0	0	0	0	0	22·6*	29·1*	0
Spring Feed	D.M.E.	0	0	0	0	0	0*	18·1	105·6
Summer Feed	D.M.E.	162·2	0	0	0	393·7	427·7	446·7	446·7
Autumn Feed	D.M.E.	648·6	526·5	0	0	0	0	0	0
Winter Feed	D.M.E.	148·6	150·4	70·6	95·2	32·4	0	0*	87·4
OPPORTUNITY COSTS									
" Change "	£/acre	3·05	2·15	1·94	1·91	0·58	0·58	0·58	0·57
Arable Land	£/acre	4·10	3·20	3·01	3·00	2·90	2·90	2·90	2·90
Non-Arable Land	£/acre	1·05	1·05	1·07	1·09	2·32	2·32	2·32	2·34
Spring Feed	£/D.M.E.	0·52	0·52	0·38	0·36	0	0*	0*	0
Summer Feed	£/D.M.E.	0	0·56	0·15	0·15	0	0	0	0
Autumn Feed	£/D.M.E.	0	0	0·04	0·04	0·77	0·77	0·77	0·77
Winter Feed	£/D.M.E.	0	0	0	0	0	0*	0*	0
Oat Supply	£/acre	1·57	1·57	1·15	1·09	0	0	0	0
" Legume "	£/ac.yr.units	0	0·18	0·20	0·20	0·15	0·15	0·15	0·15
Winter Wheat Rotation ..	£/acre	1·27	1·31	1·54	1·57	2·15	2·15	2·15	2·15
Oats	£/acre	4·78	3·87	4·11	4·16	5·15	5·15	5·15	5·15
Native Pasture I	£/acre	0·26	0·26	0·04	0·04	0·77	0·77	0·77	0·77
Native Pasture II	£/acre	1·04	0·26	0·04	0·04	0·77	0·77	0·77	0·77
Lucerne I	£/acre	3·26	0·52	0·36	0·36	0	0	0	0
Lucerne II	£/acre	3·78	0·52	0·22	0·22	0	0	0	0

* Oat Supply in disposal is equivalent to surplus Winter-Spring feed.

TABLE 2

Plans Computed from Matrix A—Pasture Coefficients 33 per cent. Lower than Observed Mode

	Unit	Plan Number					
		I	II	III	IV	V	VI
Arable Areas	....	0	82·6	745·4	887·8	948·9	1000
Enterprises							
Spring Wheat Rotation	Acres	0	45·1	407·3	485·1	518·5	546·4
Winter Wheat Rotation	Acres	0	0	0	0	0	0
Sheep	Ewes	360·4	373·0	406·3	411·9	385·2	362·8
Lucerne I	Acres	0	37·5	84·3	126·3	0	0
Lucerne II	Acres	0	0	253·8	276·4	430·4	453·6
Native Pasture I	Acres	0	0	0	112·2	51·5	0
Native Pasture II	Acres	1000	917·4	254·6	0	0	0
Oat use	Acres	0	14·9	134·4	160·1	171·1	180·3
Oats	Acres	0	0	0	0	0	0
Revenue (£)	....	698	904·3	2426·6	2750·8	2833·5	2902·6
Surpluses							
Oat Supply	Acres	0	0	0	0	0	0
Spring Feed	D.M.E.	0	0	0	0	0	105·6
Summer Feed	D.M.E.	108·1	0	0	0	387·0	446·7
Autumn Food	D.M.E.	432·4	365·5	0	0	0	0
Winter Feed	D.M.E.	99·1	104·4	64·6	91·7	31·9	87·4
OPPORTUNITY COSTS							
" Change "	£/acre	3·40	2·50	2·30	2·28	1·35	1·35
Arable Land	£/acre	4·10	3·20	3·00	3·01	2·90	2·90
Non-arable Land	£/acre	0·70	0·70	0·70	0·73	1·55	1·55
Spring Feed	£/D.M.E.	0·52	0·52	0·38	0·36	0	0
Summer Feed	£/D.M.E.	0	0·56	0·15	0·15	0	0
Autumn Feed	£/D.M.E.	0	0	0·04	0·04	0·77	0·77
Winter Feed	£/D.M.E.	0	0	0	0	0	0
Oat Supply	£/acre	1·57	1·57	1·15	1·09	0	0
" Legume "	£/ac.yr./unit	0	0·18	0·20	0·19	0·15	0·15
Winter Wheat Rotation	£/acre	1·27	1·31	1·54	1·57	2·15	2·15
Oats	£/acre	4·78	3·87	4·11	4·16	5·15	5·15
Native Pasture I	£/acre	0·26	0·26	0·04	0·04	0·77	0·77
Native Pasture II	£/acre	0·69	0·26	0·04	0·04	0·77	0·77
Lucerne I	£/acre	3·26	0·52	0·38	0·36	0	0
Lucerne II	£/acre	3·78	0·52	0·22	0·22	0	0

TABLE 3

Plans Computed from Matrix A—Pasture Coefficients 50 per cent. Higher than Observed Mode

	Unit	Plan Number					
		I	II	III	IV	V	VI
Arable Acres	....	0	167·7	867·6	946·5	976·5	1000
Enterprises							
Spring Wheat Rotation	Acres	0	91·7	474·1	517·2	533·6	546·4
Winter Wheat Rotation	Acres	0	0	0	0	0	0
Sheep	Ewes	806·8	757·7	472·9	439·2	396·4	362·8
Lucerne I	Acres	0	76·1	98·1	134·6	0	0
Lucerne II	Acres	0	0	295·4	294·7	442·9	453·6
Native Pasture I	Acres	0	0	0	53·5	23·5	0
Native Pasture II	Acres	1000	832·3	132·4	0	0	0
Oat Use	Acres	0	30·2	156·5	170·7	176·1	180·3
Oats	Acres	0	0	0	0	0	0
Revenue (£)	....	1562·7	1836·5	2824·5	2932·7	2915·9	2902·6
Surpluses							
Oat Supply	Acres	0	0	0	0	0	0
Spring Feed	D.M.E.	0	0	0	0	0	105·6
Summer Feed	D.M.E.	242·0	0	0	0	398·3	446·7
Autumn Feed	D.M.E.	968·1	742·4	0	0	0	0
Winter Feed	D.M.E.	221·9	212·0	75·2	97·7	32·8	87·4
OPPORTUNITY COSTS							
" Change "	£/acre	2·54	1·63	1·41	1·37	— 0·57	— 0·57
Arable Land	£/acre	4·10	3·19	3·01	3·00	2·90	2·90
Non-arable Land	£/acre	1·56	1·56	1·60	1·63	3·47	3·47
Spring Feed	£/D.M.E.	0·52	0·52	0·38	0·36	0	0
Summer Feed	£/D.M.E.	0	0·56	0·15	0·15	0	0
Autumn Feed	£/D.M.E.	0	0	0	0·04	0·77	0·77
Winter Feed	£/D.M.E.	0	0	0	0	0	0
Oat Supply	£/acre	1·57	1·57	1·15	1·09	0	0
" Legume "	£/ac.yr.unit	0	0·18	0·20	0·19	0·15	0·15
Winter Wheat Rotation	£/acre	1·27	1·31	1·54	1·57	2·15	2·15
Oats	£/acre	4·78	3·87	4·11	4·16	5·15	5·15
Native Pasture I	£/acre	0·26	0·26	0·04	0·04	0·77	0·77
Native Pasture II	£/acre	1·56	0·26	0·04	0·04	0·77	0·77
Lucerne I	£/acre	3·26	0·52	0·36	0·36	0	0
Lucerne II	£/acre	3·78	0·52	0·22	0·22	0	0

The computer may be led to print one of these instead of the other, with the computing routine used, because of positive opportunity costs (normally rounding errors) of magnitude less than 1×10^{-6}

These programmes were solved using routine M36 on SILLIAC; the electronic computer at the Basser Computing Laboratory, University of Sydney.

It is worth noting that in a plan such as III of Table 1 (where feed is limiting in three of the quarters) a rounding error can produce a spurious surplus in one quarter, and hence the print-up show a zero opportunity cost on disposal in that particular quarter. Normal checking routines will disclose such errors.

TABLE 4

Computed Plans for Arable Acreage between 150 *and* 450 *on a* 1,000 *Acre Property*

	Unit	Acres Arable			
		150	250	350	450
Enterprises					
Spring Wheat Rotation	Acres	82·1	136·4	190·4	246·0
Winter Wheat Rotation ..	Acres	0	0	0	0
Sheep	Ewes	533·2	519·9	506·5	492·9
Lucerne I	Acres	55·7	61·1	66·6	72·1
Lucerne II	Acres	12·5	52·1	91·5	132·0
Native Pasture I	Acres	0	0	0	0
Native Pasture II	Acres	850.0	750.0	650.0	550.0
Oat Use	Acres	27·1	45·0	62·9	81·2
Oats	Acres	0	0	0	0
Revenue (£)	..	1363.0	1556.0	1748.0	1944.0
Surpluses					
Oat Supply	Acres	0	0	0	0
Spring Feed	(D.M.E.)	0	0	0	0
Summer Feed	(D.M.E.)	0	0	0	0
Autumn Feed	(D.M.E.)	502·8	427·5	352·8	275·9
Winter Feed	(D.M.E.)	146·5	135·4	124·1	112·4

TECHNICAL CONSIDERATIONS IN THE COMPUTED PLANS—"CURRENT TECHNOLOGY"

The plans computed are considered to be conservative in the precautions taken to maintain soil fertility and control black oats. In practice lucerne would probably be established under a cover crop of wheat and the inclusion of a fourth crop of wheat in the rotation in this way would increase the revenue from arable land and the non-arable to arable "change facility" by approximately 13s. 7d. per acre per year.

Settlers with whom the plans were discussed considered them feasible and were in fact endeavouring to adjust their farm organization to approximate that suggested. The July lambing date suggested did not coincide with current practice, and in consequence they were inclined to include more oats than suggested. Against this it was agreed that slight adjustment of lambing dates would be expected to permit use of lucerne in place of oats and that sheep revenue differences would be slight.

FEED SUPPLIES AND FODDER CONSERVATION

The imposition of restraints based on fertility maintenance and weed control results in considerable quantities of feed becoming available, in the present periods of shortage, as a by-product of cash crop production. Under these circumstances it is unprofitable to devote any additional acreage to the production of grazing oats. At low arable acreages, spring feed, and at high, autumn feed, become the most important limiting factors in sheep production. Relatively little summer and spring feed surplus to requirements is available in any plan.

Since one D.M.E. per three months is roughly equivalent to three bales of lucerne hay, some estimate of the possibilities of fodder conservation can be deduced from the plans.

Consider Plan II of Table 1 (coefficients as modal estimates, 119 acres arable per 1,000). Surplus lucerne would be available in Autumn, which might be conserved to permit more sheep to be carried in spring and summer. The marginal revenue product of a D.M.E. of feed in Summer is £0.56 and in Spring £0.52. It is clear from inspection of the "sheep" column of the matrix in Appendix I that roughly equal quantities of spring and summer feed are needed by a ewe (within the order of accuracy of the estimates given) so that the addition to revenue by hand feeding a sheep for the six spring and summer months would be £1.08 for six D.M.E. months, or roughly 3s. 10d. per bale of lucerne.

Potential returns from possible alternate fodder crops can also be gauged from the computed plans. The M.V.P.'s of Plan V in Table 1, for example, show that some additional sheep could be carried by providing autumn feed alone. The revenue per unit of autumn feed is £0.77, while the cost of arable land disposal is £2.90. If we assume that the cost of establishing a hypothetical autumn fodder crop is x, then the amount of autumn feed it must produce to break even is $\frac{£2.90 + x}{0.77}$ D.M.E., or a minimum of about four dry sheep per acre. The cost x above might be required to cover additional fencing besides cultivation, seeding, etc.

The "Synthetic Plans"

Table 5 shows the optimum cropping programme given choice between the two rotations based on current practice on the settlement and two alternative rotations, 11 and 12, based on both experiment results obtained by one of us (J.D.F.) and on the practice of one or two landholders on properties nearby. It will be seen that rotations 11 and 12, if they can be followed, permit substantially higher revenue[11] than the plans of Tables 1 to 4. Rotation 11 is more diversified, and contains both summer and winter cash crops, making use of cowpeas as a fertility builder ("legume") and sorghum as part of the black oat control measures.

[11] It must be appreciated that in all cases the "revenue" computed must be reduced by the total of fixed costs such as rent, rates, depreciation and all other charges which are not affected by the method of land use adopted.

TABLE 5
Plans Computed from Matrix B

	Unit	*B*1. Pasture Coefficients at Observed Mode — Plan Number I	II	III	*B*2. Pasture Coefficients 33% Lower than Observed Mode — Plan Number I	II	III	*B*3. Pasture Coefficient 50% Higher than Observed Mode — Plan Number I	II	III
Arable Acres	....	0	311·1	1000	0	231·4	1000	0	402·6	1000
Enterprises										
Spring Wheat Rotation	Acres	0	0	0	0	0	0	0	0	0
Winter Wheat Rotation	Acres	0	0	0	0	0	0	0	0	0
Sp. Wheat-Milo-Cowpea	Acres	0	222·2	714·3	0	165·3	714·3	0	287·6	714·3
Sp. Wheat-Oats-Milo	Acres	0	0	0	0	0	0	0	0	0
Lucerne I	Acres	0	88·9	180·7	0	66·1	180·7	0	115·0	180·7
Lucerne II	Acres	0	0	105·0	0	0	105·0	0	0	105·0
Native Pasture I	Acres	0	0	0	0	0	0	0	0	0
Native Pasture II	Acres	1000·0	688·9	0	1000·0	768·6	0	1000·0	597·4	0
Oat Use	Acres	0	0	0	0	0	0	0	0	0
Oats	Acres	0	0	0	0	0	0	0	0	0
Sheep	Ewes	540·5	444·4	203·3	360·4	330·6	203·3	806·8	575·2	203·3
Revenue (£)	....	1047·0	2220·8	4765·2	698	1651·9	4765·2	1562·7	2874·2	4765·2
Surpluses										
Oat Supply	Acres	0	0	0	0	0	0	0	0	0
Spring Feed	D.M.E.	0	0	0	0	0	0	0	0	0
Summer Feed	D.M.E.	162·2	0	0	108·1	0	0	242·0	0	0
Autumn Feed	D.M.E.	648·6	577·8	491·8	432·4	429·8	491·8	768·1	747·8	491·8
Winter Feed	D.M.E.	148·6	211·1	315·4	99·1	157·0	315·4	221·9	273·2	315·4
OPPORTUNITY COSTS										
"Change"	£/acre	5·13	3·77	3·69	5·48	4·12	4·05	4·62	3·26	3·17
Arable Land	£/acre	6·18	4·82	4·77	6·18	4·82	4·77	6·18	4·82	4·77
Non-arable Land	£/acre	1·05	1·05	1·07	0·70	0·70	0·71	1·56	1·56	1·60
Spring Feed	£/D.M.E.	0·52	0·52	0·38	0·52	0·52	0·38	0·52	0·52	0·38
Summer Feed	£/D.M.E.	0	0·56	0·15	0	0·56	0·15	0	0·56	0·15
Autumn Feed	£/D.M.E.	0	0	0	0	0	0	0	0	0
Winter Feed	£/D.M.E.	0	0	0	0	0	0	0	0	0
Oat Supply	£/acre	1·57	1·57	1·15	1·57	1·57	1·15	1·57	1·57	1·15
"Legume"	£/ac.yr.units	0	0·34	0·38	0	0·34	0·38	0	0·34	0·38
Sp. Wheat-Oats-Milo	£/acre	0·26	1·72	1·89	0·26	1·72	1·89	0·26	1·72	1·89
Oats	£/acre	6·86	5·50	5·87	6·86	5·50	5·87	6·86	5·50	5·87
Spring Wheat Rotation	£/acre	1·51	2·97	3·21	1·51	2·97	3·21	1·51	2·97	3·21
Winter Wheat Rotation	£/acre	2·82	4·29	4·75	2·82	4·29	4·75	2·82	4·29	4·75
Native Pasture I	£/acre	0.26	0·26	C·04	0·26	0·26	0·04	C·26	0·26	0·04
Native Pasture II	£/acre	0·26	0·26	0·04	0·26	0·26	0·04	0·26	0·26	0·04
Lucerne I	£/acre	4·75	0.52	0·36	4·75	0·52	0·36	4·75	0·52	0·36
Lucerne II	£/acre	5·28	0·52	0·22	5·28	0·52	0·22	5·28	0·52	0·22

5. USE OF THE COMPUTED PLANS IN DECISION MAKING

On the basis of answers to the survey questionnaire the following problems were exercizing the farmers' minds:—

(1) What is the nature of a stable crop farming pattern for the district?

(2) Should arable land be devoted to fodder crop production?

(3) What returns can be expected from an arable cropping system of land use?

(4) How much can be spent in developing an acre of arable land?

(5) How much untillable land can be included in a "cultivation" paddock?

It was evident that most farmers had already decided that all readily developed land should be devoted to arable cropping. After programming it appears that acceptable and reasonably specific answers can be provided to these questions.

Fodder Crops

The question of fodder cropping has been discussed above. The computed marginal revenue products for feed in the four quarters of the year provide an acceptable basis for evaluation of fodder crops *per se* at any period of the year. Given the high output of feed from the postulated rotations it would appear that fodder crops are most likely to find a place on the farm with a high proportion of arable land.[12] But even then acreage would be comparatively limited, and since feed is required from August to January it may be difficult to find a single crop to match profitably the pattern of feed needs with the "synthetic" rotation.

Returns from Arable Land

The marginal revenue product of the "change" facility in the computed plans supplies an estimate of returns with varying proportions of arable land.

In the practical farm situation there are two facets of this problem—the short and the long term. In the short term machinery, earthworks, and fencing, and sometimes water supplies, must be financed. The survey disclosed that settlers in the main have no serious problems in providing machinery. Even with 1,000 acres arable no more than 430 acres of wheat is required in the computed plans. In some cases existing plant is probably unsuitable for the best operation of such acreages but it might be expected that acreage would be increased gradually, which would permit makeshift arrangements in many cases.

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[12] It should be noted that a property with, say, 100 acres arable would grow from 55 to 70 acres of wheat per year on average. In some circumstances it may not be economic to own a harvester for such a small acreage and such cases would require examination in the light of machinery availability, possibilities for contract work, and so forth.

The trend may well be towards plant with a higher capital value per arable acre with possible excess capacity on some farms. Some settlers are already meeting this problem in part by sharefarming and the use of contractors.

The crop vectors used allow an annual charge of £1 10s. 0d. per acre against utilized machine capacity which would be available to help in meeting commitments on equipment purchased on terms. In some cases there may be reason for advances for machinery purchase from a special fund for War Service Settlers.

Earthworks for erosion control can cost as much as £15 per acre on limited areas, although the normal charge is much less: £5 appears to be a common estimate among farmers. Up to 40 per cent of the treated area may be unsuitable for cropping because of the loss of land in banks and waterways, but 15 to 20 per cent appears more usual.

On the basis of 100-acre paddocks, fencing costs might be as high as £3 to £4 per acre. Where grassland is enclosed with arable it is not a complete liability. Assuming the suggested eleven year spring wheat-barley-oats rotation is followed, spring, autumn, and winter use of the grassland is obtained during the five years under lucerne. Summer grazing is available during the four years when wheat and barley are grown, and spring and winter grazing in the two years when oats are cultivated. The value of the gazing can be estimated from the computed M.V.P.'s of fodder disposals.

In the next section we attempt to outline the financial consequences of a decision to expand crop production on a previously uncropped property. It is assumed, in the absence of evidence to the contrary, that sub-division and deferred grazing, and the proximity of crops and lucerne, will have no beneficial or adverse affect on the grazing provided by this grassland.

Expanding Crop Acreage—A Hypothetical Example

Assume that a property of 1,000 acres has 400 acres which can be fenced and developed for cultivation. Because of stone and surface irregularities only 80 per cent can be contour banked to yield 80 per cent of the treated area clear of banks and headlands. Thus 36 per cent of the fenced area will be in grass.

Assume that contour banking costs £5 per treated acre and fencing and the provision of water £4 per fenced acre.

Reference to Table 5 (group B1) shows that currently 540.5 ewes will be run with revenue of £1,047 net of variable expenses.

Capital costs of development will be:—

400 × £4	= £1,600 (fences)
400 × .8 × £5	= £1,600 (banks)
Total	= £3,200

The yield of arable land will be 400 × .8 × .8 or 256 acres.

The property as now considered is equivalent to one of 856 acres with 256 acres arable, with an additional 144 acres of grassland which cannot be fully utilized.

The "optimum" way to organize the 856 acres considered alone is as 0.856 of a 1,000 acre property with $\frac{256 \times 1000}{856} = 299$ acres arable; i.e., a linear combination of Plan I and Plan II of group B1 of Table 5, and comprises:—

Rotation II	182.3 acres
Lucerne I	73.1 acres
Native Pasture II	600 acres
Surplus summer feed ..	5.7 D.M.E.
Surplus autumn feed ..	497.0 D.M.E.
Surplus winter feed ..	178.6 D.M.E.
Sheep (ewes)	383.7
Revenue	£1,879

So the added return on investment of £3,200 is £832 net or 26 per cent.

Of the 144 acres of grassland, assume $\frac{4}{14}$ will be associated with lucerne I, $\frac{4}{14}$ with wheat not followed by cowpea, $\frac{2}{14}$ with cowpea followed by milo, $\frac{2}{14}$ with milo, and $\frac{2}{14}$ by cowpea grazed in the fourteen-year rotation.

This grassland can be grazed as follows:—

D.M.E. of Feed Available

	Spring	*Summer*	*Autumn*	*Winter*
$\frac{4}{14}$ lucerne	82·4	..	82·4	61·8
$\frac{4}{14}$ wheat	..	123·6	..	..
$\frac{2}{14}$ cowpea—milo	..	..	..	30·9
$\frac{2}{14}$ milo	..	..	..	30·9
$\frac{2}{14}$ cowpea grazed	..	..	61·8	..
	82·4	123·6	144·2	123·6

Spring remains the most limiting quarter and 82.4 D.M.E. of feed values at £0.5235 per unit are available from enclosed grassland in that period. Additional revenue of £43.14 can be secured by adding 22.27 sheep to the figure of 383.3 computed earlier.

So total revenue under the new plan is increased by about £875 in comparison with the no-arable plan.

In practice the result in the first few years after clearing may be a little better, since the whole area would probably be sown to wheat for the first three years, then to cowpea and milo. At about this stage the first lucerne sowings would be made, and there would be a drop in income. On the remainder, grazed cowpea followed by wheat would probably be the next crops in the rotation.

Following such a plan would reduce spring feed by 73.1 x 3.0 or 219.3 D.M.E. and furthermore the 82.4 D.M.E. from "grass adjacent to lucerne" would not be available. The net result of such a plan would be the reduction of sheep numbers to 324.

However, wheat income from 256 acres of wheat for the first three years would be £1,915, and from 324 sheep £628, a total of £2,543, or £1,496 per annum more than that received when the farm was used for grazing alone. At the outset about 215 sheep could be sold, adding perhaps £300 to available capital. In addition capital and interest charges of £1 10s. per acre of machine capacity, charged as a variable cost against the crop activities, would be available to reduce a loan to purchase equipment or improvements by a further £384 per annum.

A landholder who decided to introduce cropping in the above situation might install erosion control works and boundary fences at the outset, requiring an outlay of say £2,400 and repayments of perhaps £300 in the first year. About September, cultivation would commence. It would probably be unnecessary to reduce sheep numbers until ploughing commenced and the proceeds of sheep sales would be approximately the amount required to meet his first year's repayment on the development of erosion control works and fencing.

Sales of sheep would reduce sheep income by £412 to £631 (from which rent and other fixed charges must be met). Since it is unlikely that the settler will have accumulated savings of any significant size, it is apparent that a loan of at least £412 for living expenses, of some £3 per acre of crop sown, say £768, (and special terms to permit acquisition of machinery in those cases where none is at present on the property) would be needed in the first year. However, given average seasons, the settler should be able to service all debts thereafter and pay for machinery—if necessary—within three years. If obliged to repatriate borrowings as rapidly as this the settler would experience a slight improvement in living standards at the outset and signficant improvement thereafter.

6. RECAPITULATION—SALIENT POINTS OF THE PLANS COMPUTED

The salient points emerging from the plans computed during the study appear to be these:—

(1) Cash crop rotations based on current practice produce sufficiently greater revenue per unit area, relative to native pasture, that they can supplant the latter. This is so even if some parts of the acreage diverted to crops is not fully utilized because of stone, erosion control structures, and similar obstructions to complete cultivation. This situation would persist with lower crop prices than at present, given reasonable efficiency in crop production.

As an example, in a situation where Plan III of Table I should be followed (814.5 to 922.3 acres arable per 1,000) a fall in net wheat price of £0.31 per bushel, *Ceteris Paribus,* would require to take place before the plan become suboptimal. The spring wheat rotation produces 60 bus. wheat over 11 years, and a restraint on "charge" costs £1.94 per annum at the margin: $\frac{1.94 \times 11}{69} = 0.31$. Tables 2 and 3 indicate the change to be made from an enterprise mix based on Table 1 if the return to sheep was 33 per cent lower or, alternatively 50 per cent higher than the modal estimates.

(2) The return to sheep enterprises, combined with the practical possibilities for approximate matching of feed requirements and production, does not appear to justify the diversion of arable land to special fodder crops outside the minimum likely to be incorporated in arable crop rotations.

(3) More "efficient" rotations than those commonly adopted at present can be devised. These minimize the costs of meeting restraints imposed by the need to maintain "soil fertility" and control weeds in the wheat crop.

(4) The survey discloses that most settlers have sufficient machinery to increase cash cropping substantially. Relatively small amounts of capital would be required to increase income in many cases. Although settlers might have difficulty providing the capital from their own resources, they should be able to repay development loans fairly quickly.

APPENDIX I

Input—Output Matrices

MATRIX A

Production Possibilities Derived from Settlers Modal Estimates of Input-Output Relationships

	B	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
		Spring Wheat Rotation	Winter Wheat Rotation	Sheep	Oats	Native Pasture I	Native Pasture II	Lucerne I	Lucerne II	Oat Use	'Change' Activity NAL-AL
" Change "	0	0	0	0	0	0	0	0	0	0	+ 1
Arable Land (Acres) (A.L.)	0	1·0	1·0	0	1·0	0	0	1·0	1·0	0	— 1·0
Non-arable Land (Acres) (N.A.L.)	1000	0	0	0	0	1·0	1·0	0	0	0	1·0
Spring Feed (D.M.E.)	0	0	— 1·8	3·7	0	— 1·5	— 2·0	— 3·0	— 2·0	— 3·0	0
Summer Feed (D.M.E.)	0	— 1·0	— 1·0	3·4	0	— 3·0	— 2·0	0	— 2·5	0	0
Autumn Feed (D.M.E.)	0	0	0	2·5	0	— 3·0	— 2·0	— 2·0	— 2·0	0	0
Winter Feed (D.M.E.)	0	0	— 1·8	2·5	0	— 1·5	— 1·5	— 2·0	— 1·0	— 3·0	0
Oat Supply (Acres)	0	— 0·33	— 0·33	0	— 1·0	0	0	0	0	1·0	0
" Legume "	0	5·0	5·0	0	0	0	0	— 6·0	— 6·0	0	0
Z — C (£)	0	— 4·10	— 2·0	— 1·937	2·25	0	0	0·15	0·15	0	0

NOTES.—The coefficients of the " legume " row ensure that the stipulated rotations are followed within any activity mix.

Unit D.M.E., that is the energy requirements of an adult merino ewe, neither pregnant nor lactating, for normal maintenance and wool growth over a three month period, in the case of feed requirements and output. Sheep—a breeding ewe and her normal supporting stock, approximately 3 per cent rams, all lambs, and ewe hoggets. Wethers sold as hoggets, 70 per cent lambing, 5 per cent death losses, all ewes normally culled by fifth lambing. Unit " sheep " as so defined corresponds to a maximum of approximately 1·7 flock sheep at some time of the year.

MATRIX B

Expanded Production Possibilities Using Rotations Suggested by Research Projects

	B	P_1 Spring Wheat Rotation	P_2 Winter Wheat Rotation	P_3 Sheep	P_4 Oats	P_5 Native Pasture I	P_6 Native Pasture II	P_7 Lucerne I	P_8 Lucerne II	P_9 Oats	P_{10} 'Change' Activity NAL-AL	P_{11} Spring Wheat Oats Milo Rotation	P_{12} Spring Wheat Milo Cowpea Rotation
" Change "	0	0	0	0	0	0	0	0	0	0	+1	0	0
Arable Land (Acres)(A.L.)	0	1·0	1·0	0	1·0	0	0	1·0	1·0	0	— 1·0	1·0	1·0
Non-arable land (Acres) (N.A.L.)	1000	0	0	0	0	1·0	1·0	0	0	0	1·0	0	0
Spring Feed (D.M.E.)	0	0	— 1·8	3·7	0	— 1·5	— 2·0	— 3·0	— 2·0	—3·0	0	0	0
Summer Feed (D.M.E.)	0	— 1·0	— 1·0	3·4	0	— 3·0	— 2·0	0	— 2·5	0	0	— 1·0	— 0·6
Autumn Feed (D.M.E.)	0	0	0	2·5	0	— 3·0	— 2·0	— 2·0	— 2·0	0	0	0	— 0·6
Winter Feed (D.M.E.)	0	0	— 1·8	2·5	0	— 1·5	— 1·5	— 2·0	— 1·0	—3·0	0	— 1·0	— 0·5
Oat Supply (Acres)	0	— 0·33	— 0·33	0	—1·0	0	0	0	0	1·0	0	— 0·17	0
" Legume "	0	8·3	8·3	0	0	0	0	—10·0	—10·0	0	0	8·3	4·0
Z — C (£)	0	— 4·10	— 2·0	—1·937	2·25	0	0	0·15	0·15	0	0	— 5·65	— 6·10

NOTES.—The coefficients of the " legume " row ensure that the stipulated rotations are followed within any activity mix. P_{11} and P_{12} are the " synthetic " rotations.

Units:—One D.M.E. is the energy requirement of an adult merino ewe, neither pregnant nor lactating, for normal maintenance and wool growth over a three-month period, in the case of feed requirements and output. Sheep—a breeding ewe and her normal supporting stock, approximately 3 per cent rams, all lambs, and ewe hoggets. Wethers sold as hoggets, 70 per cent lambing, 5 per cent death losses, all ewes normally culled by fifth lambing. Unit " sheep " as so defined corresponds to a maximum of approximately 1·7 flock sheep at some time of the year.

APPENDIX II

Enterprise Budgets

Crop Budgets

(I) *Spring Wheat*—

	s.	d.
Average expected yield 24 bushel/acre.		
Assume 1 bushel saved for seed.		
Expected price per bushel 14s. (ex Board Charges).		
Gross Revenue per acre—		
23 x 14s.	322	0
Costs per acre—		
Hail insurance at 8d./bushel	15	4
Cartage to rail at 8d./bushel	15	4
Rail freight at 2s. 3d. per bushel	51	9
Machinery running costs	60	0
Machinery holding costs	30	0
Net revenue for acre of spring wheat	149	6

(II) *Barley*—

	s.	d.
Average expected yield 30 bushel/acre.		
Assume 1 bushel saved for seed.		
Expected price 9s. per bushel.		
Gross Revenue per acre—		
29 x 9s.	261	0
Costs per acre—		
Cartage at 8d./bushel	19	4
Bags at 8d./bushel	19	4
Machinery running costs	60	0
Machinery holding costs	30	0
Net revenue per acre of barley	132	5

(III) *Oats*—

	s.	d.
No grain yield.		
Costs per acre—		
Machinery running costs	40	0
Seed	5	0
Total cost per acre of oats	45	0

(IV) *Grain Sorghum*—

	s.	d.
Average expected yield 30 bushel/acre.		
Expected price 7s. per bushel in the paddock.		
Assume negligible seed cost (3 to 7 lb. only).		
Gross revenue per acre—		
30 x 7s.	210	0
Cost per acre—		
Bags at 7d./bushel	17	0
Machinery running costs	50	0
Net revenue per acre of grain sorghum	143	0

(V) *Winter Wheat*—

	s.	d.
Average expected yield 16 bushel/acre.		
Assume 1 bushel saved for seed.		
Expected price per bushel 14s. (ex Board Charges).		
Gross Revenue per acre—		
15 x 14s.	210	0

	s. d.
Costs per acre—	
Hail insurance at 8d./bushel	10 0
Cartage to rail at 8d./bushel	10 0
Rail freight at 2s. 3d. per bushel	33 9
Machinery running costs	60 0
Machinery holding costs..	30 0
Net revenue per acre of winter wheat	66 3

(VI) *Lucerne—*

Lucerne sown under last wheat crop.

Costs per acre—	
4 lb. seed at 3s. 6d. per lb.	14 0
Therefore cost of an acre of lucerne per year	3 0

Sheep Budget

1,000 Breeding ewe flock.
No culling other than cast for age.
Wethers sold as hoggets.

Assume—

Lamb marking 70 per cent.
Death losses 4 per cent.

	£
Revenue—	
Wool—	
Ewes—960 x 8 lb. at 56d.	1,792
Lambs—700 x 3·5 lb. at 36d.	367
Wether hoggets 330 at 50s.	829
c.f.a. ewes 176 at 20s.	176
	3,164
8 rams per year	200
Shearing, drenching, etc. 9s. per sheep	797
Wool selling costs	230
Net Revenue	£1,937
Net Revenue per breeding ewe	£1·937

Spring Wheat Rotation Budget

Crop	Revenue	Feed Produced (D.M.E.)			
		Spring	Summer	Autumn	Winter
	£				
Wheat	7·48	..	1·5	..	..
Wheat	7·48	..	1·5	..	..
Wheat	7·48	..	1·5	..	..
Barley	6·63	..	1·5	..	..
Oats	— 2·25	3·0	..	..	3·0
Oats	— 2·25	3·0	..	..	3·0
Total	24·57	6·0	6·0	0	6·0
Av. over 6 yrs. crop	4·10	1·0	1·0	0	1·0

WINTER WHEAT ROTATION BUDGET

Crop	Revenue (£)	Feed Produced (D.M.E.)			
		Spring	Summer	Autumn	Winter
Wheat	3·31	1·6	1·5	..	1·6
Wheat	3·31	1·6	1·5	..	1·6
Wheat	3·31	1·6	1·5	..	1·6
Barley	6·63	..	1·5	..	..
Oats	— 2·25	3·0	..	..	3·0
Oats	— 2·25	3·0	..	..	3·0
Total	12·06	10·8	6·0	0	10·8
Av. over 6 yrs. crop ..	2·0	1·8	1·0	0	1·8

SPRING WHEAT—OATS—MILO ROTATION BUDGET

Crop	Revenue (£)	Feed Produced (D.M.E.)			
		Spring	Summer	Autumn	Winter
Wheat	7·48	..	1·5	..	..
Wheat	7·48	..	1·5	..	..
Wheat	7·48	..	1·5	..	..
Barley	6·63	..	1·5	..	..
Oats	— 2·25	3·0	..	..	3·0
Milo	7·15	..	..	..	3·0
Total	33·97	3·0	6·0	0	6·0
Av. over 6 yrs. crop ..	5·65	0·5	1·0	0	1·0

SPRING WHEAT—MILO—COWPEA ROTATION BUDGET

Crop	Revenue (£)	Feed Produced (D.M.E.)			
		Spring	Summer	Autumn	Winter
Wheat	7·48	..	1·0	..	..
Wheat	7·48	..	1·0	..	..
Cowpea	4·00	..	..	..	1·5
Milo	7·15	..	..	..	1·0
Cowpea	— 3·00	..	..	3·0	..
Wheat	7·48	..	1·0	..	..
Wheat	7·48	..	1·0	..	..
Cowpea	4·00	..	..	..	1·5
Milo	7·15	..	..	..	1·0
Cowpea	— 3·00	..	..	3·0	..
Wheat	7·48	..	1·0	..	..
Wheat	7·48	..	1·0	..	..
Total	61·18	0	6·0	6·0	5·0
Av. over 10 yrs. crop ..	6·1	0	0·6	0·6	0·5

APPENDIX III

Summary of Replies to Survey Questionnaires

Crops

WHEAT

Twenty respondents provided estimates of wheat yields. The average of the estimates was 24 bushels per acre and the range was 15 to 33 bushels. There was a clear-cut correlation[13] between the stated date of first cultivation of wheat land and expected yield, which was approximately 3 bushels higher for each extra month between initial working and sowing. The stated date of first working ranged from November to March, and sowing date in most circumstances was in the May-June period.

Ten of the settlers had sown significant quantities of winter wheat with an average yield estimate of 16 bushels per acre. The majority of these settlers regarded winter wheat as supplying good winter feed, comparable to the output of grazing oats, and possessing the advantage of a reasonable cash return at harvest. However, black oats and mintweed became more of a problem under this crop, while there have been reports that winter wheat varieties provide conditions for a substantial increase in the severity of rust infestations by harbouring this disease from autumn onwards.

Policy with respect to grazing wheat varied. Winter wheat was usually grazed between May and August at rates ranging from one to six sheep per acre. Spring wheat stubbles were grazed after harvest and occasionally the fallow was grazed. Few settlers said they needed sheep to graze the crop as an insurance against frost damage. In fact, only two settlers grazed spring wheat between sowing and harvest. There are virtually no sales of premium wheat from this area.

OATS

Seventeen settlers grew oats, of these there were four who never stripped oats, grazing the crop out. All others grazed their oats and harvested some grain, for an average yield of 18 bushels per acre (range 9-30 bushels). This was either sold or used as a drought reserve. No cooperator grew oats solely for grain. An oats crop was commonly used as a weed control measure, being grazed right out in early spring to combat black oats. Where this was done grain sorghum was sometimes the succeeding crop. There is a tendency to replace oats with winter wheat grazed right out on some properties, as the crop shows less tendency to run to head if the late autumn is dry.

BARLEY

Sixteen settlers grew barley and of this number only four used the crop for grazing. Mainly this crop was grown with the objective of sale for malting purposes. Expected yields ranged from 21 bushels per acre to 36 bushels per acre, somewhat higher than, and correlated with, anticipated

[13] $r = 0.8$ on 16 d.f. The yield in bushels is given by $Y = 19.23 + (2.7)m$., where m is months from first preparation to sowing.

wheat yields. The average yield estimate was 30 bushels per acre. The cultivation of barley was regarded by all growers as an integral part of the black oat control programme. Barley stubbles were assessed as supplying slightly more grazing than wheat stubbles.

Grain Sorghum

Ten of the settlers had grown grain sorghum and only a few of these considered it as having a regular place in their rotation. Throughout the North-Western slope and North Central plain divisions there is a tendency to grow "milo" in bad wheat seasons, commonly to make use of unsown fallows. The average expected yield was 30 bushels per acre. However, four of the growers claimed their results to be so uncertain they could not specify an expected yield. Although useful amounts of winter grazing can be secured from sorghum stubble, most growers commented on the difficulty of reverting to winter crops following sorghum—land must lie idle for 8-10 months under present practices. This is a serious drawback where arable land is limited. Another factor against consistent inclusion of sorghum in a cropping programme is the fact that it has virtually no value for drought insurance in the Spring of sowing. The "synthetic" rotation appears to minimize these difficulties and take advantage of sorghum as a "cleaning" crop in black oat control.

The estimated price received for grain sorghum was £13 10s. 0d. per ton "in the paddock", the usual basis of sale. It appeared that under some circumstances better returns might have been secured by storing the grain while negotiating with buyers. Such sales were the result of growers seeking ready cash rather than avoiding the extra work involved in storing and protecting the grain.

Lucerne

Eighteen settlers grew lucerne (85 acres average, range 7-180). Of the five that did not grow lucerne three intended to grow it the next year. Most of the eighteen were in favour of lucerne and had increased their acreage over the last few years: two intended to increase it further. Two settlers claimed it tended to harbour mintweed and did not like it on this account. (One settler had reduced his lucerne acreage.) This problem might be reduced with more rigorous rotational practices.

The special virtues of lucerne are its perenniality, low seeding and upkeep costs, and its comparatively high resistance to scarab damage. Suitably managed it provides significantly superior forage to native pasture in periods of possible critical feed shortage.

Five settlers stated that they grew lucerne principally as a hay crop.

The practice of overseeding oats into lucerne stands is very common on the settlement and all respondents considered that it was of benefit to the lucerne to be treated in this manner. The authors are not aware of any experimental investigation of this practice and consider that an evaluation of its effect on total output and longevity of lucerne stands would be of widespread interest.

One problem in the management of lucerne, in common with wheat and other cash crops, was stated to be the difficulty of locating fences so that extensive areas of non-cultivatable grassland are not included with arable land. This difficulty arises from the presence of a network of small water-courses and stony outcrops which, on most properties, reduce the use which can be made of the grass so enclosed and add to fencing costs. Water supplies also present problems in subdivision, as mentioned in the section dealing with them specifically.

Cowpeas

There is little experience of cowpeas on the settlement although some nearby landholders have had good results with the crop. At the time of the survey only one settler interviewed claimed to have had experience with the crop, harvesting 6½ bushels of clean seed per acre from 31 acres. He proposed to sow the crop again. A yield of 9 bushels has been assumed in programming, and such yields are common nearby. The price of clean seed was assumed to be £1 per bushel. The market for cowpea seed has been reasonably sure to date with prices ranging upwards from about £1 per bushel. The crop has an obviously beneficial effect on the yield of the next subsequent wheat or fodder crop.

General Considerations in Soil Management

Considerable developmental work has been necessary, and more will still be required if arable acreage is to be extended. Of the 28,206 acres in the 23 survey properties 7,950[14] are currently cultivated or could be cultivated with little capital outlay (except perhaps fencing). An additional 3,220 acres is judged by the owners to be suitable for cropping if cleared, and in some cases stone-picked and/or contour banked, at costs estimated to average between £6 to £8 per acre, although some areas may cost as much as £15-£20 per acre to develop with adequate erosion control measures.

There seems little doubt that much of the area will ultimately be developed, but lack of capital, or unwillingness or inability to borrow and to employ hired labour, are significantly delaying such progress. It will be clear from the analysis in the text that marginal returns to such investment are potentially satisfactory.

An adverse aspect of erosion control work was pointed out by several settlers who had installed water control structures. They estimated that the amount of arable land yielded after such work was approximately 80 per cent of the area treated. This deflates expected returns quite significantly.

Surface stone also presents problems. Some country at present uncultivated on this account might be worked with tyned implements with a fairly high breakage rate. In the heavy outcrops a technique, and suitable species of pasture plant, to establish a sward by surface broadcasting or aerial methods might be valuable.

A technique for establishing lucerne without cultivation would partly meet requirements. A species is required which provides almost year-round grazing quite inexpensively and which can persist in the presence of the black soil scarab.

[14] This area has increased since the survey was completed.

MACHINERY AVAILABILITY

Of the 23 settlers interviewed, only four had insufficient machinery to permit cultivation and harvesting of the full potentially arable acreage on their properties. One stated that he normally arranged for harvesting to be undertaken by an outside contractor.

The investment in machinery was relatively constant, most settlers estimating that to replace their existing plant with new equipment would cost approximately £2,800. The average plant was estimated to be capable of handling approximately 300 acres of wheat. Machine capital invested per acre of capacity, about £9, was some 30 per cent lower than estimates for specialized wheat growers in the nearby Pallamallawa-North Star district, partly reflecting the common use of smaller tractors. The use of such plant may contribute to the difficulties of timely preparation of wheat land, but on the other hand many of the settlers had a high outlay per acre of *utilized* machine capacity. Quite commonly this difficulty had been minimized by judicious purchase of items of second-hand equipment, and most settlers expect an average useful life of 10 to 12 years for their farming plant.

Livestock

SHEEP

Nineteen settlers interviewed were running merino sheep and rearing replacements. (One settler raised corriedales.) Three were raising fat lambs using purchased border-merino crossbred mothers. Among merino breeders twice as many retained the wether portion as sold wethers as hoggets. The former practice in merino management appears slightly more profitable and is often necessitated by a low lamb marking percentage.

Some settlers were interested in the possible benefits to be derived from a change to wether flocks. The results of programming the properties seem to favour this change, provided the efficiency of current stock enterprises cannot be raised and suitable supplies of wethers are available for purchase.

The majority of settlers indicated that the depreciation on a purchased wether was comparatively low provided culls could be sold as fats. The average estimated price of a two-tooth wether was £2 5s. and the expected sale price of culls at about six years was £1 to £1 10s.

The average expected clip per sheep was as follows:—

Lambs	3.5 lb.
Ewes	8 lb.
Wethers	10 lb.

The estimated price received for wool was fairly consistent at about 56d. (36d. for lambs wool) for the 1959-60 selling season. This figure was checked against account sales in many instances.

Efficiency in Sheep Husbandry

The authors believe that a more intensive study of the efficiency of sheep raising on the settlement might assist the settlers. Expected clip per head varied considerably and could not be clearly related to any of a number of factors affecting feed supply including stocking rate, percentage of scarab infested pasture, or fodder crop acreage as a percentage of total land utilized for grazing purposes. Stocking rate was associated closely with assessment of drought frequencies and past drought experience. Many of the more highly stocked properties had sheep "on the road", or on agistment, or were obliged to hand feed to a significant extent, as frequently as once every four years. There was general agreement that the drought period was likely to be at the end of Winter, broadly in "Spring" as defined.

None of the settlers appeared to consider that the genetic quality of their flocks was significantly above average and several commented on the difficulties of improvement in relatively small flocks with the low culling rates possible.

Lamb Marking Percentages

Lamb marking percentages seemed unduly low, ranging from 40 per cent to 80 per cent. A common explanation was the depredations of foxes, but it seems likely that the general low plane of nutrition of ewes lambing mostly in late winter may contribute to the result, as feed is of poor quality in late winter and spring rain fairly uncertain.

CATTLE

Eighteen of the settlers were running cattle at the time of the survey, but numbers were low. Many stated rather ruefully that they had been carrying too many cattle in 1957 and 1958, which were dry years, and had found it necessary to sell off at low prices. They now considered cattle too expensive to buy, although most "liked to have a few on the place". From the expected price of young stock, £30 (heifers), and the widespread stands of plains grass on most properties, it might be considered that a proportion of cattle could be run profitably, but a prerequisite appeared to be inexpensive measures to make the properties more "drought proof". Most settlers stated that because of price uncertainty they now felt that the "three-in-one" deal in cattle (i.e. purchase of an in-calf cow with calf at foot) was the best proposition; but from limited observation it appears that the uncertainties and long-time span involved in cattle breeding are serious disadvantages on such small properties, where capital is generally scarce.

Possibly the diversification and additional sources of revenue which would follow more intensive cash cropping would make an increase in cattle numbers more desirable than at present. Although cattle present more worries than sheep in drought periods, their lower labour requirements may make them complementary with crop enterprises, which tend to reduce drought susceptibility. On balance, sheep may still be the better proposition, if the farms are reorganized as suggested, because they permit greater flexibility in management.

The most usual shearing time was August to October but some used an autumn (March) shearing, claiming fewer off shears losses. These differences appeared to be related mainly to the owner's personal taste in organizing a particular property. A policy of increased cropping would almost certainly favour an earlier (July-August) lambing, and it appeared that no special obstacle existed to such a practice. Some slight adjustment of shearing times might be required if this change were made.

Stock Watering Facilities

Most of the survey group of settlers stated that stock watering facilities imposed constraints on the sub-division necessary for increased cropping. In many cases water points were few and on the boundaries of the property. Piping, troughs, and more mills appeared to be a normal prerequisite to further sub-division. Seventeen properties required sub-division before additional cropping could be undertaken. The most common estimate of the cost of needed fencing and water points was approximately £4 10s. per additional cropped acre.

Black Soil Scarab

An estimated 4,235 acres of the 28,206 acres in the twenty-three survey properties was stated to be obviously affected by black soil scarab, that is, about 14 per cent of total area. However, substantial amounts of the 8,000 acres under crop had been affected earlier. The scarab causes little damage to annual crops and cultivation appears to reduce scarab populations.

The most usual estimate of reduction in pasture productivity when scarab was present lay between 60 per cent and 75 per cent. The average estimate was 60 per cent but estimates ranged from zero to 100 per cent. Proportion of property infested ranged from under 3 per cent to 40 per cent. As mentioned earlier, it was not found possible to correlate output of livestock products with proportion of scarab infested pasture.

APPENDIX IV

Some Statistics Relating to Gragin Estate

The original Gragin station was 34,000 acres in extent, and was settled in 1947 by thirty soldier settlers. The settlers had to cope with severe rabbit infestation at least as late as 1949. The following estimates of population and output were made in 1954 by officers of the New South Wales Department of Lands, and were supplied by the District Surveyor, Moree.

	Before W.S.L.S.	*Under W.S.L.S.* 1952-53
Population	62	126
Sheep Numbers	32,000	32,229
Wool Production	650 bales	739 bales
Cattle Numbers	600	308
Wheat	Isolated sharefarming only.	4,039 acres
Wheat Production	....	45,000 bags
Oats	....	4,750 bags
Hay	....	125 tons
Pasture and Lucerne Area	Lucerne grown but area unknown (probably fairly large).	608 acres lucerne 563 acres pasture
Clearing	Little cleared country	8,103 acres.