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OPTIMAL GROWTH STRATEGIES FOR PASTORAL FIRMS IN THE QUEENSLAND BRIGALOW SCHEME

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The Brigalow Scheme has been one of Australia's largest dryland development projects since World War II. Large sums of private and public capital have been invested to create 247 new farm firms. Planning the development of these new properties is a complex task. A simulation model of the typical block in Area III of the Brigalow Scheme has been constructed and used to evaluate experimentally the financial performance of various growth strategies. Use of a conjugate directions search procedure with this model has allowed growth strategies to be identified which maximize net worth subject to a low risk of financial failure. These strategies are compared with development programmes which have already been implemented. Significant conclusions are reached both with respect to future management strategies and future land development policies. Methodological advances incorporated in the simulation model are also discussed.

The Brigalow Scheme was one of the most carefully researched projects in the history of Commonwealth Government involvement with land development.¹ After detailed technical and economic inquiries, the Bureau of Agricultural Economics reported in 1962 that more intensive development of 3.8 million hectares in the northern portion of the so-called Brigalow belt,² would be profitable from a national viewpoint. According to the Bureau, the project could be expected to yield approximately 12 per cent on the total capital needed [3, p. 40]. Furthermore, using an annual interest rate of 5.5 per cent, the benefit to cost ratio for the project was estimated to be of the order of 1.5 [3, p. 31]. Presumably on the basis of this evidence, the Commonwealth Government passed legislation to be known as the *Brigalow Lands Agreement Act* 1962-73 which, together with the Queensland Government's *Brigalow And Other Lands Development Act* 1962-74, initiated the Land Development (Fitzroy Basin) Scheme now well known as the 'Brigalow Scheme'. The Australian Government initially agreed to finance the scheme by advancing up to \$14.5 million to the Queensland Government as a loan repayable by 1995 with an interest rate equivalent to the long-term bond rate. Subsequently, the drawing rights of the Queensland Government under the scheme were increased to \$23 mil-

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¹ See Hoffman [15, p. 237] and Bureau of Agricultural Economics [3].

² Brigalow (*Acacia harpophylla*) and associated species are to be found in a strip up to 320 kilometres wide running from Collinsville in Queensland to Narabri in New South Wales. Originally the Brigalow plant association covered approximately 9 million hectares of Eastern Australia.

lion provided the money was used before 1 July 1975. By that date the Queensland Government had, in fact, only drawn or committed a total of \$18.55 million. In addition to the Commonwealth loan money, both state and local government authorities have spent considerable sums on administrative and advisory personnel as well as infrastructures. The scheme has been administered and implemented by the Queensland Land Administration Commission (L.A.C.) in two over-lapping stages. Brigalow Areas I, I(A) and II were settled between 1963 and 1973. Area III, the most northerly portion of the land being developed and the region of principal concern in this paper, was settled between October 1968 and June 1975. In total, the Brigalow Scheme has created 247 new farm-firms. Of these, 170 farms were allocated by ballot and 77 were sold by auction [23].

The major aim of the study being reported in this paper has been to determine optimal strategies for farm-firm growth in Area III of the Brigalow Scheme.³ In the Brigalow Scheme settlers who were successful in the ballots were given the opportunity to acquire their new farms with a minimum equity. Provided they abide by the development conditions laid down, they can eventually obtain freehold title to the land. Specifically, in regard to Area III, the minimum initial capital required was \$36,000. The new settlers in Area III could obtain development loans of up to \$72,000 from the L.A.C. and of up to \$55,000 from the Commonwealth Development Bank.⁴ In addition, the L.A.C. advanced the purchase price of the land, typically of the order of \$40,000, as an interest-free loan repayable over 25 years. The total borrowings available to settlers on ballot blocks in Area III, therefore, could be as high as \$167,000.⁵ With such large amounts of public and private capital at risk, appropriate growth strategies are important from the viewpoint of both the individual settler and the nation.

Upon taking possession of their blocks, the new settlers were required to make a series of complex management decisions in regard to the allocation of the available finance for farm growth. While the ability to perceive growth opportunities has sometimes been viewed as a 'growth problem' [28], this is not an issue for Brigalow land selectors who must fulfil certain property development (or growth) conditions as specified in their lease agreement. Three major sets of decisions concerning farm development may be identified. These relate to: land clearing and pasture establishment (with associated fencing and pro-

³ Area III, which is predominantly north of the Tropic of Capricorn, differs significantly with regard to climate and other physical features from Areas I, I(A) and II, all of which are south of the Tropic. Furthermore, conditions of settlement in Area III were different; for example, Area III blocks have been typically much larger and the initial equity requirement was 50 per cent greater.

⁴ The L.A.C. development loans are repayable over 25 years, with interest payments only for the first five years of this period. Initially the L.A.C. charged Area III settlers annual interest rates of 6.125 per cent. However, in 1976 the rate of interest was 10.325 per cent. The Commonwealth Development Bank development loans have been typically for 12 years, with interest payments only for the first two years. Interest rates have been comparable with those charged by the L.A.C.

⁵ Actual borrowings have also been of this order. For example, a representative sample of Area III settlers was surveyed in 1974. At that time these people had been on their blocks for periods ranging from one to five years. For these settlers, the mean level of debt in 1974 was \$143,000 [12, p. 70].

vision of stock water); control of scrub regrowth; and acquisition of livestock.⁶ While estimates of costs and returns associated with certain given property development programmes have been made,⁷ the study reported in this paper is the first systematic attempt to compare the economic desirability of a range of alternative growth strategies and to determine strategies which are optimal with respect to the objectives of the land selectors involved.

1 *Research Procedure*

The typical firm in Area III of the Brigalow Scheme is a complex bio-economic system with numerous and interacting relationships involving elements of climate, soil, pastures and grazing animals, plant and equipment. The economic performance of this system is under the control of an individual (or family) and is constrained by product and factor markets, and by institutional arrangements. The most desirable strategy for growth will vary with the physical, financial and managerial resources available to each land selector. Estimates of performance under a given growth strategy need to be made for a number of years and to take account of fluctuating prices and climatic uncertainty. The complexity of the planning situation has implications for the choice of a research procedure with which to investigate the problems involved.

On *a priori* grounds a range of research methodologies could be considered as feasible research procedures for examining farm growth strategies in the Brigalow Scheme. These include whole-farm development budgeting, mathematical programming (e.g. multi-period, stochastic and quadratic programming), dynamic programming and systems simulation. Simulation was finally chosen for this study due to its greater flexibility in regard to modelling, particularly with respect to uncertainty, non-linear relationships and multiple management goals.⁸ The potential of this technique for farm growth research has been illustrated by previous studies.⁹ Simulation has traditionally been considered inferior to programming techniques in regard to the discovery of optimal solutions to planning problems [1]. Nowadays, this deficiency can be substantially overcome by incorporating optimum seeking procedures such as the 'steepest ascent' technique [32] or 'random search with heuristic learning' [10] into the simulation model. The potentially high cost of constructing a simulation model has also been a traditional obstacle to wider use of the technique. In this simulation study of farm growth in the Brigalow Scheme, special attention has been devoted to the questions of optimization and model construction costs.

1.1 *Outline of the Simulation Model*

The management planning problem being investigated may be formulated symbolically as follows:

⁶ While some cash cropping has been carried out in Brigalow Area III, the heavy initial capital requirement, transport costs and climatic uncertainty, could be expected to limit this growth option to only a few settlers. Therefore, cropping was not considered as a feasible growth alternative for the typical new settler in Area III.

⁷ For references on these budgets see Harrison [12, Ch. 4].

⁸ Guidelines for choosing between alternative farm planning techniques have been laid down by Irwin [16].

⁹ See, for example, Charlton and Street [4], Eidman *et al.* [6], Eisgruber and Lee [7], Patrick and Eisgruber [24] and Walker and Halbrook [30].

optimize $Z = g(P)$
 where $P = f(X, Y, S, A)$
 and Z is the value to the decision maker of implementing a particular management policy;
 P is a vector of endogenous variables;
 $g(P)$ is the objective function which translates the multiple performance measures into a single index of achievement;
 X is a vector of controllable variables (the policy or decision space);
 Y is a vector of non-controllable variables (or 'states of nature');
 S is a vector of initial states of the status variables; and
 A is a vector of similar parameters.¹⁰

Optimization of Z is constrained by the requirement that $X \geq 0$ while initial resource supplies specified in S constrain resource use.

The function $f(X, Y, S, A)$ represents the model of the typical farm-firm in Brigalow Area III. The elements of P express the outcome resulting from a given X . Each X is in fact a growth strategy and $g(P)$ is the multi-dimensional objective function of the land selector. The model is, in effect, a procedure, expressed in symbolic language and programmed for a computer, which has been designed to predict the level of Z for a given X under a specified environmental sequence Y . This prediction process can be repeated under a range of different environmental sequences to obtain estimates of expected net worth and the probability of failure. Superimposed on the prediction procedure is a search routine which systematically adjusts the levels of the decision variables (elements of X) until the objective function is optimized. Optimization experiments are carried out for various resource bases as specified by the vector S . This research procedure is illustrated by Figure 1.

The simulation of the operations for each year, which is the central component of the research procedure, is presented in greater detail in Figure 2. As shown in this Figure, the annual operations simulator consists basically of three submodels dealing respectively with pastures; livestock; and investment and finance. In the pasture submodel, rainfall is synthesized for each week throughout the similar year. A soil-water balance routine is then used to predict resultant weekly available soil moisture. Based on current and past available soil moisture, the condition of both natural and improved pastures in each week throughout the year is classified as good, fair, poor or droughtstricken. A complex system of carry-overs of good and fair pasture conditions following high and moderate soil moisture levels has been devised for this purpose [12, Ch. 8].

Predicted pasture conditions are used in the determination of live-weight gains and consequent turnoff weights in the livestock submodel. Calving rate and extent and timing of stock sales are also related to pasture conditions. The numbers of livestock in various classes are recorded on an annual basis and vary with purchases, sales, natural increase and mortalities. Herd size is constrained by the carrying

¹⁰ The classification of elements of the model adopted here is based on Orcutt [22].

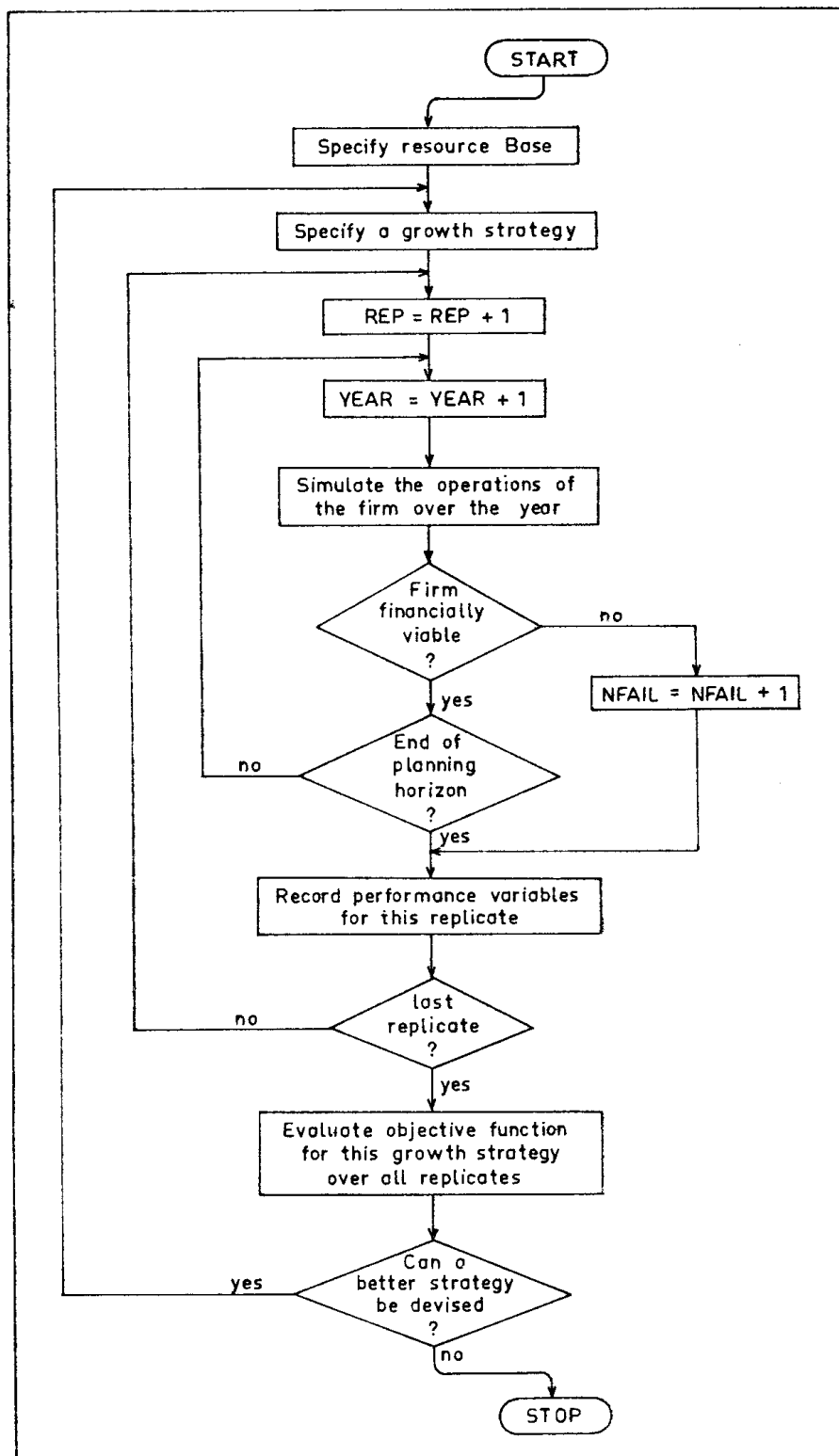


FIGURE 1—Research Procedure.

capacity of the property and this may be increased through land development or regrowth treatment.

The investment and finance submodel keeps account of capital outlays, annual income and expenditure, debt servicing and income tax payments on a financial year basis. The planned growth for each year in terms of land development, regrowth control and breeder purchases is tested for financial feasibility and, should insufficient funds be available, is reduced to the maximum feasible level. In this regard cash funds are assumed to be drawn on before unused borrowing capacity, and breeder purchases have priority over other forms of investment. Inflation is built into the model by adjusting family and business expenditures according to simulated annual values of the Consumer Price Index and the Index of Prices Paid by Farmers.¹¹ The level of the funds owned by the settler after allowing for all inflows and outflows indicates whether the firm remains financially viable at the end of the year. If this balance is negative an amount of up to \$15,000 is assumed to be available in the form of either short-term credit from a pastoral finance company or a bank overdraft. Should the deficit exceed \$15,000 the settler is assumed to be in arrears with his longer term loan repayments. Once these loan repayment arrears exceed \$35,000 the firm is considered to be no longer financially viable.¹²

Data for construction of the model have been obtained from two farm surveys (in 1972 and 1974), Australian official statistics, published and unpublished experimental results and discussions with various subject area specialists. Details of validity and sensitivity tests of the model are provided elsewhere [12, Chs. 10 and 13]. Based on survey evidence, the objective function of the typical settler has been formulated as follows:

$$\begin{aligned} &\text{maximize} && Z(ENW_n | P \leq P^*, C_t \geq C_t^*) \\ &\text{where } ENW_n && \text{is expected net worth at the end of the planning horizon;} \\ &P && \text{is the probability of financial failure over the planning horizon and } P^* \text{ the acceptable upper limit for the probability;} \\ &C_t && \text{is consumption, and } C_t^* \text{ the subsistence level, during each year } t; \text{ and} \\ &t = 1, 2, \dots, n, && \text{where } n \text{ is the planning horizon in years.} \end{aligned}$$

According to this lexicographic function, settlers first aim to maintain financial viability and, given this can be achieved, seek to make sufficient cash withdrawals to meet essential consumption. Provided these 'constraint goals' are met, an attempt is made to maximize the rate of growth of the firm.¹³ Maximum tolerable failure probabilities reported by

¹¹ These price indices correspond to the official statistical series as published in various issues of the *Commonwealth Year Book* and *Quarterly Review of Agricultural Economics*, respectively.

¹² The financial failure criterion was established after consultation with lending authorities. The figure of \$35,000 corresponds to about two years redemption payments at high debt levels. By early in 1977 it is understood that a significant proportion of the settlers in Brigalow Area III have failed financially according to this criterion, but as yet there has been only one foreclosure [23].

¹³ Eisgruber and Lee [7] argue that owner/managers of a growing firm will derive infinite utility from subsistence consumption but zero utility from further

settlers during the farm surveys ranged from 0.1 to 0.3 [12]. A value of 0.2 has been adopted in the analysis. Estimates of essential consumption expenditure at 1975 prices were also calculated from survey data. On the basis of these calculations, the analysis assumes an initial annual cash allowance for essential private consumption of \$4,500 at 1975 price levels. During the simulation experiments this figure is adjusted annually according to simulated values of the Consumer Price Index. The planning horizon has been set at 15 years since exploratory growth experiments revealed that a shorter period would not provide reliable estimates of failure probabilities. A further early finding was that iso-net worth and iso-risk contours are very similar in shape (i.e., that growth and security are not conflicting goals).¹⁴ The objective function was thus simplified to maximization of expected net worth subject to annual consumption constraints.

1.2 *Some Special Features of the Model*

The simulation model briefly outlined above incorporates a number of methodological innovations. These range from fundamental physical/biological aspects such as the procedure developed for synthesizing the weekly rainfall series; to the treatment of institutional considerations created by the Australian income tax laws; to the final structure of the computer programme itself.

1.2.1 *Rainfall Synthesis*

The procedure adopted for generating the weekly rainfall sequences was basically that suggested by Phillips [25]. However, statistical tests on rainfall records for recording stations in the region revealed persistence (or correlation in excess of seasonality).¹⁵ In this study, therefore, the rainfall distributions for each week were made conditional on the level generated for the previous week. To achieve this a 10 x 10 transition matrix of weekly rainfall with states bounded by decile levels, was estimated from historical data for Bombandy (centrally located in Area III). The conditional distribution for rainfall in the current week, given the rainfall of the previous week, was expressed in cumulative form. A random number drawn from a uniform distribution was used to sample a decile class from the cumulative distribution. A second uniformly distributed random number was then employed to sample

(luxury) consumption. While this may appear to be an extreme view, the settlers interviewed in Brigalow Area III gave answers to questions about their goals which were consistent with the Eisgruber/Lee hypothesis [12, Ch. 6].

¹⁴ An exploratory farm-growth experiment enabled iso-net worth and iso-risk contours to be plotted. The experiment employed a 4 x 4 factorial design with land clearing levels of 0, 1,000, 2,000 and 3,000 hectares and breeder purchases of 400, 500, 600 and 700 allocated arbitrarily over time, each strategy being evaluated over 30 different environmental sequences. The two sets of curves were convex to the origin and similar in shape.

¹⁵ The three rainfall recording stations were Bombandy, Dingo and Twin Hills. These three stations were selected both because they were representative of Area III and because records had been kept for a sufficiently long period in each case. The statistical tests carried out on these rainfall data included tests on frequencies of runs above and below weekly and monthly medians and on auto-correlation coefficients of de-seasonalized weekly and monthly rainfall. Tests were also applied to the transition matrices for rainfall in successive weeks. For further details, see Harrison and Vadlamudi [14].

within the selected decile range using the bracket median approach devised by Phillips [25].

1.2.2 *Generation of Price and Cost Data*

Three beef price series (light bullocks, females and boners), changes in the Consumer Price Index, and changes in the Index of Prices Paid by Farmers were all generated on a quarterly basis. To incorporate both correlations between these variables and autocorrelations within each series over time, sampling was carried out from a conditional multivariate normal distribution. Chi-squared tests revealed that logarithmic transformations of historical levels of the variables (after adjustment of prices for trend and seasonality) did not differ significantly from normal distributions. Values of the five transformed variables in the current quarter (Y_1) and lagged one quarter (Y_2) were modelled as a 10-variate normal distribution. A standard procedure for sampling from the multivariate normal distribution [21] was then applied to the conditional distribution $h(Y_1|Y_2 = Y_2^*)$, but with the vector of means (U_1) being continuously adjusted in accordance with actual values generated for the previous time period (Y_2^*).¹⁶ Inverse transformations were finally applied to obtain the random price components and cost index movements.

1.2.3. *Income Tax Considerations*

An income tax routine is included in the model which takes account of such complexities of the Australian tax legislation for primary producers as the progressive rates scale, averaging of incomes, carrying forward of business losses, provisional tax, indexation of tax rates, and average cost valuation for determination of profit on livestock.¹⁷ The ability to determine accurately tax payments on given income streams is seen as an important advantage of simulation over programming techniques where cumbersome approximation procedures must be used.

1.2.4 *Determination of Optimal Strategies*

Optimal growth strategies have been derived by the method of conjugate directions originally devised by Powell [26]. Basically, the method of conjugate directions is an interactive approach to finding the unconstrained optimum when derivatives of the function to be optimized cannot be evaluated directly. It has the important property of being quadratically convergent (i.e., the exact optima of a quadratic form can be obtained in a finite number of iterations). Since many objective functions can be approximated by a quadratic form in the region of the optima, the method is relatively robust for business management applications. Further, it appears to be more efficient than many of the alternative procedures for unconstrained optimization [9].

One iteration of the search procedure involves a sequence of optimizations in linearly independent directions, initially chosen as the co-ordinate axes of the response hypersurface (i.e., in the direction of each of the strategic variables in turn). Subsequent iterations introduce

¹⁶ The algebra of the conditional multivariate normal distribution is provided in [20, pp. 212-215].

¹⁷ For further details see Harrison and Carrick [13].

new search directions which are pairwise conjugate.¹⁸ Optimizations in these directions involving simultaneous adjustments to a number of variables allow interactions between variables to be taken into account. The search may be terminated when changes in the levels of all variables become small or when the objective function cannot be improved by further iteration.

Although use of the conjugate directions method to obtain optimal management policies in simulation studies has been suggested in the past [8], it does not appear to have been applied previously to models of farming systems. In this study, resource and non-negativity constraints were introduced by way of barrier penalty functions [2]. After other relatively minor modifications, the Powell procedure appeared quite successful for identifying optimal growth strategies for Brigalow land selectors, provided the number of decision variables was limited to less than about ten. Beyond this number of decision variables optimization became increasingly costly and unreliable.

1.2.5 *Modular Approach to Model Construction*

Construction of bio-economic simulators by the linking together of a series of modules transferable to future studies, has been advocated in the literature as a potential means of reducing the cost of the simulation technique [5]. The Brigalow farm-growth simulator has been programmed for the computer as a number of relatively self-contained modules with minimal linkages to the main program. As a result it was found that not only were the costs of model construction (labour and computer time) reduced, but also it became easier to concentrate attention on the development and validation of the more difficult parts of the model. Furthermore, the various modules (e.g., rainfall generator, price and cost index generator, soil-water budgeting procedure, income tax assessment routine, and the optimization procedure) are all readily available for future studies.¹⁹ In fact, the income tax module has already been incorporated in a subsequent study [13].

2 *Conditionally Optimal Growth Strategies*

Most development on ballot blocks in Brigalow Area III takes place in the first five years from selection, during which time loan finance through the L.A.C. is available to settlers. In this study attention was focused on growth strategies during this period of external financing, subsequent property development being assumed to take place as rapidly as internally generated income permits. Opportunities for growth are defined in terms of seven strategic variables, viz., areas of land cleared and sown to improved pastures in years 1, 3 and 5 (x_1 to x_3 respectively); areas of scrub regrowth subjected to chemical control in years 3 and 5 (x_4 , x_5); and numbers of breeders purchased in years 1 and 2 (x_6 , x_7).²⁰ Expenditure on fencing and water supply facilities are functionally related to the area cleared and to the increase in carrying capacity respectively.

¹⁸ If the quadratic form is written in matrix-vector notation as

$$Z = \frac{1}{2}X'GX + b'X + c$$

then the vectors u_i and u_j are said to be conjugate with respect to the matrix G if

$$u_i'Gu_j = 0 \text{ for } i \neq j$$

¹⁹ The FORTRAN IV program is available from the authors.

²⁰ Up to 15 strategic variables were included in preliminary similar experiments.

The optimal growth strategy for an individual land selector depends on the resources at his command as represented by the initial values of status variables in the set S . In this context, the strategy which maximizes terminal net worth for a given resource base may be viewed as a conditionally optimal strategy. The aim of simulation experiments is thus to find the X set (written X^*) which maximizes net worth under typical S and to examine how X^* varies with variations in the initial levels of individual status variables s_j in the conditional functional

$$f(X^*, Y, \{s_{k,k \neq j}\}, A | s_j)$$

Resource bases S have been defined by setting status variables at median values (as observed in the 1974 survey) and by varying them one at a time by 20 per cent in the upwards and downwards directions.

Initial resources which are varied in this study are restricted to the equity of the settlers (typically \$45,000), loan finance for land development and for stock purchases (limited to \$72,000 and \$55,000 respectively), and land resources. Typical levels of the latter are 3600 ha. of scrub and 2400 ha. of forest land, each further divided into a number of classes and stages of development. For simplicity, when adjusting land resources initial areas in each class have been varied by the same proportion. In addition to these resource variations, simulation experiments have been performed for different interest rates on the external finance. Typical interest rates are 9 per cent on term loans and 14 per cent on short term credit. Each interest rate is adjusted by the same proportion.

Similar experimentation for each separate resource base was found to involve the evaluation of approximately 100 different growth strategies. Cost considerations, therefore, limited encounters with the model to five per strategy. Optimal levels of the seven decision variables, totals for each growth subset and mean terminal net worth are presented in Table 1. This table indicates that a settler with typical initial resources would maximize expected net worth by clearing approximately 1500 ha. of scrub land during the five-year period of external financing. Although spread throughout the period, nearly half of this is in the fifth year. Also included in the optimal strategy is 800 ha. of regrowth spraying, of which 500 ha. is in year 5. Purchase of 545 breeders is indicated as optimal, and most of these should be obtained in the first year. A net worth at the end of year 15 of about \$382,000 can be expected under this strategy.

The total areas of land clearing and regrowth control in the conditionally optimal strategy are relatively unchanged if initial settler's funds are reduced by 20 per cent.²¹ However, these activities should be deferred within the five-year period (e.g., only 600 ha. of land development and no regrowth control are carried out before year 5). Also, the optimal level of stock purchases is reduced to below 500 head and expected terminal net worth falls by about \$75,000 (20 per cent). On the other hand, higher initial funds (of \$54,000) favour earlier land development and regrowth control and increased breeder purchases.

²¹ That is, while other initial resource levels are held fixed at the typical level, initial settlers' funds are set at \$36,000, the minimum amount which was required of ballot applicants in Area III.

TABLE I
Optimal Growth Strategies for Various Initial Resource Levels

Status Variable or Resource	Policy or Decision Variables									
	Land Development			Regrowth Control			Breeder Purchases			Mean Terminal Net Worth After 15 Years
	x_1	x_2	x_3	Total Land Development in First 5 Years	x_4	x_5	Total Regrowth Control in First 5 Years	x_6	x_7	
	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)	(no.)
All Resources Initially at Typical Levels	491	362	676	1,529	324	498	822	462	83	381,613
Initial	198	403	990	1,591	0	698	698	450	84	305,971
Initial Funds	755	517	460	1,732	378	474	852	475	139	444,839
Resource										
Development	528	385	302	1,215	40	178	218	430	110	379,601
Levels										
Loans	510	359	783	1,652	274	555	829	463	83	384,136
Relative										
to										
Stock Loans	222	687	650	1,559	353	668	1,021	400	80	298,355
Typical										
Levels	792	440	654	1,886	85	452	537	472	130	419,653
Interest Rates	515	655	450	1,620	462	303	765	431	117	415,410
Property Size	764	293	273	1,330	395	538	933	459	106	318,949
Property Size	878	269	427	1,610	368	406	774	388	138	287,564
Property Size	417	474	547	1,438	172	276	448	466	102	441,827

Net worth is increased by over \$60,000 (16 per cent). The initial level of settlers' funds limits the number of foundation livestock which may be acquired, and performance is highly responsive to the stock purchase variables.

If loan funds for development purposes are reduced by 20 per cent, the total area of land clearing declines to 1200 ha., and regrowth control of only 200 ha. during the period of external financing is optimal. However, the reduction in breeder purchases is marginal and net worth declines by only \$2,000 (0.5 per cent). At a higher level of development funds the table indicates little change in the optimal strategy or net worth. These results suggest that the response hypersurface is quite flat or insensitive with respect to levels of the land development and regrowth control variables.

If the maximum stock loan is 20 per cent below the typical maximum level of \$55,000, then breeder purchases are reduced to 480 head. In this case higher land development and regrowth control in the middle and later part of the five-year period are optimal. Twenty per cent higher stock funds favour earlier clearing, less regrowth control and an increase in breeder purchases to 600 head. Changes in net worth of -\$83,000 (-22 per cent) and +\$38,000 (10 per cent) accompany lower and higher stock funds respectively, revealing the importance of this resource.

As indicated in Table 1, a reduction in interest rate has little effect on the optimal growth strategy though a moderate increase in net worth takes place. Higher interest rates appear to favour regrowth control rather than land development. Although the optimal level of breeder purchases is increased a moderate reduction in net worth relative to that under typical resource levels is indicated in the table.

A 20 per cent reduction in property size has little effect on the optimal total amount of land development and regrowth control during the first five years. However, these activities should be carried out at earlier dates (e.g., optimal land development in year 1 is increased by 400 ha.). A smaller number of breeders can be depastured at selection but purchases in the second year are increased by more than 50 head. Terminal net worth falls by almost \$100,000 (25 per cent), much of which would be attributed to the reduced value of land. A 20 per cent increase in property size favours less land development and regrowth control but greater breeder purchases during the initial five-year period. A substantial increase in net worth accompanying the larger area is also indicated by Table 1.

3 *Optimal versus Actual Growth Strategies*

In late 1974 a representative sample of 18 settlers in Area III was interviewed and details both of initial resources and of actual development strategies implemented were recorded. These people had been on their blocks for from one to five years. Initial resource bases were relatively uniform between settlers except in regard to equity. Some settlers had begun with less than the statutory minimum (i.e., less than \$36,000) while others had invested over \$100,000.

Observed strategies differed from the optimal strategies generated by the model in a number of respects. Land clearing had been more

rapid, settlers typically clearing scrub in blocks of 1,000 to 1,500 ha.²² Eleven of the 18 had pulled more than 1,000 ha. in the first year and six had cleared more than 2,000 ha. in the first three years. As final net worth appears to be relatively insensitive to the rate of land development, this accelerated clearing may not have been of great overall importance.²³

A high degree of variability was observed in the number of stock (mainly breeders) purchased. Seven of the 18 had purchased more than 600 breeders. On the other hand seven had introduced 500 or fewer breeders and four of these had obtained 400 or fewer breeders.

Only two settlers had carried out any chemical control of regrowth although a substantial area is indicated as optimal both in the model and for technical reasons. It is to be noted that sensitivity analysis indicated the optimal rate of regrowth control was responsive to beef prices. However, although the beef price slump was in evidence at the time of interviews, this would have had little effect on strategies implemented up to that date. In most cases some burning had been carried out in areas affected by scrub regrowth, though experimental evidence suggests that burning is not an effective control measure [18].

4 *Main Implications and Conclusions*

A number of implications emerge from the farm-growth optimization experiments both for Brigalow Scheme land selectors and for administrators of such land development schemes. It appears to be particularly important for new settlers to acquire a large number of foundation livestock as quickly as possible. While this may appear self-evident, it has not been a feature of the actual growth strategies adopted by Area III settlers. The optimal number of foundation livestock is largely independent of interest rates and of property sizes within the ranges considered in this study (see Table 1). On smaller blocks more rapid land development would be required subsequently to provide sufficient grazing capacity. The 1974 survey revealed that livestock purchases were frequently limited by the low initial equity of the settler and inadequate access to finance for livestock purchases.

In the case of land development, a comparison of observed and conditionally optimal strategies suggests that often clearing may have been unnecessarily rapid, running well ahead of grazing needs. While the Brigalow Scheme is intended to be a land development project, it would be preferable to induce such development indirectly by assisting settlers to purchase livestock so that they may subsequently clear land and establish pastures with internally generated funds.

An absence of regrowth control was also common in observed strategies. As this appears to be due to the attitude of land selectors to regrowth control, further extension efforts in regard to regrowth control may be required.

²² The observed rate of land clearing also differs from the recommendation of the Queensland Department of Primary Industries. The Department suggests that scrub be pulled in blocks of not more than approximately 400 ha. due to the potentially high expenditure requirements for regrowth control [17].

²³ Practical difficulties such as the irregular availability of land clearing contractors undoubtedly played a part in determining the rate and timing of land development.

Unlike the situation with the purchase of foundation livestock, the implications of clearing too rapidly or failing to implement a regrowth control program are not clear-cut. The simulation model indicates that performance is relatively insensitive to changes in the levels of these decision variables. If finance had been directed away from land development towards livestock purchases, thus substantially reducing the feasible rates of clearing and regrowth control, it is unlikely that there would have been any significant effect on long run net worth. The optimal timing of scrub clearing within the five-year period of external financing depends on the rapidity with which the settler is able to stock his property. If stock acquisition is slow, land development should be deferred until cattle numbers build up through natural increase.

The examination of growth strategies in Area III of the Brigalow Scheme has implications for the planning of future land settlement schemes of a similar nature.²⁴ The simplest way for the planning authority to improve the economic viability of settlers is to increase the initial equity requirements. Of course, the higher the initial funds required the lower the proportion of land selection aspirants eligible for land ballots. A compromise must, therefore, be made between, on the one hand, the political goal of affording to as many people as possible the opportunity to acquire land and, on the other hand, the economic goal of ensuring financial viability of successful applicants.²⁵

Other means of increasing farm profitability and viability in schemes similar to the one considered here include provision of larger stock loans, lowering of interest rates on loan finance and increasing property sizes. However, the results of this study indicate that the provision of larger development loans appears to be of little or no value in this regard as far as the Brigalow Area III settlers are concerned. Reduction of interest rates may be criticized on the grounds that it constitutes favoured treatment for land selectors *vis-à-vis* other farmers and other borrowers in general. The areas of properties in Brigalow Area III appear to be adequate under a range of climatic and economic environments, and increased property size would reduce the number of holdings that could be created. On the other hand, as mentioned several times already, the provision of a higher level of finance for initial livestock purchases would be an acceptable means of enhancing the prospects of settlers.

Another important conclusion from the simulation experiments is that future land settlement schemes should provide special development finance over a longer period. Land development in the Brigalow Scheme may have been unduly rapid due to the five-year limit on concessional external financing. If settlers knew in advance that they could continue to draw on the special development funds over seven or eight years

²⁴ Australia has seen numerous government sponsored land settlement projects in the past [15], and it is probable that new schemes will be introduced in the future. The demand for farm acquisition remains strong (as evidenced by the large number of applicants in the final Area III land ballot [23]) and further projects have been investigated (e.g., in Queensland the Belyando-Suttor Region [31], a possible Brigalow Area IV, and the Burdekin River Basin [27]).

²⁵ It is to be noted that in the Brigalow Scheme land has also been released by auction, and that purchasers of auction blocks have not been eligible for L.A.C. finance. Land release by auction has, therefore, catered for demand by potential settlers with higher asset or fund levels than those entering ballots.

they would tend to be less hasty about clearing.

Finally, a word about the research methodology adopted for this study. The simulation approach was found to be well suited to the complex planning environment being examined. Although too expensive for one-off farm management studies, models of the type constructed for Brigalow Area III have a great potential for examining and planning land development schemes in which there will be many holdings with essentially similar resource bases. Furthermore, once constructed, models such as the one described in this paper can be used to investigate the farm management problems faced by settlers of some years' standing. For example, any Area III settler could experiment with the Brigalow model to evaluate alternative future strategies simply by adjusting the vector of initial states to represent his current stage of development.

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