STOCHASTIC-COMPUTERIZED-ACTIVITY-BUDGETING FOR SHEEP ENTERPRISES*

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Stochastic-computerized-activity-budgeting (SCAB) facilitates and extends the traditional gross margins analysis for sheep activities. SCAB is one of the very few computerized management aids so far developed for Australian farm management situations. In the deterministic mode SCAB calculates gross margins based on point estimates of all the relevant parameters. In stochastic mode it generates a distribution of pay-offs (gross margins) based on the manager's subjective probability distribution for the relevant major uncertain paramaters. The variance of this distribution of pay-offs represents a measure of the risk associated with the activity given the manager's current knowledge and expectations.

The aim of the stochastic-computerized-activity-budgeting (SCAB) procedure is to facilitate and extend activity budgeting and gross margins analysis. SCAB has been developed to assist farm managers to process all the relevant data both more efficiently and more rationally. The procedure not only computerizes the traditional approach but also adds a measure of risk. Although SCAB is currently only available for sheep enterprises, the concept could be extended to most livestock and crop enterprises.

The rational processing of information and expectations is an essential step in all managerial decision-making. Agricultural management decisions such as comparing the profitability of two or more alternative activities, frequently involve a large number of parameters. The values of some of these parameters will be known with certainty while others will have uncertain values at the time the decision is to be made. In relation to the uncertain parameters, most managers will have a set of multi-valued expectations for each of these variables which they can summarize in the form of a subjective probability distribution. Due to the large amount of data and the probabilistic nature of the expectations, it is frequently difficult, if not impossible, for managers to evaluate rationally all the dimensions of the decision problem by manual methods.

Computerized Management Aids

Modern electronic computers with time-sharing and remote-access terminals have made it feasible to computerize the processing of data

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for many managerial decisions.[1] Before farm managers can avail themselves of modern electronic data processing (EDP) three conditions must be satisfied. First, the necessary software (computer programs) need to be developed and properly documented. Second, field-workers need to be trained in how to use these computerized management aids. Third, the field-workers need to have access to the necessary hardware (computer facilities).

Eisgruber [12] has suggested that in the United States of America it is the second condition which has restricted the adoption of computerized management aids. A large number of computer programs have been developed and documented by research workers. For instance, Lanpher [19] lists 425 agriculturally oriented computerized management aids currently available in the U.S.A. In addition, in 1971 Walker [30] pointed out that computer terminals were rapidly becoming readily available to American extension workers. However, American County Agents have not been trained in the use of computerized management aids and they currently represent the bottleneck in the adoption of EDP for farm management [15, p. 11].

In Australia the whole concept of computerized managegment aids for farmers seems to have been neglected. The Officer and Dillon contribution in 1965 [24], the Harrison collection published in 1970 [16], the recent publication by Angus *et al.* [3] and SCAB appear to be the only Australian computerized management aids currently available for farm managers.[2] There has been no genuine attempt by an Australian extension organization (either public or private) to train field staff in the use of computerized management aids. Nor has there been any attempt to make computer hardware readily available to field-workers. As software such as SCAB become more widely available and as field-workers begin to appreciate the advantages as well as the problems associated with using computers for extension purposes, one would expect the situation in Australia to change rapidly.

The researchers developing computerized management aids have a vital role to play in encouraging the use of EDP in agricultural decision-making. There is a need for a continuing inter-relationship between the decision-maker, the extension-worker and the researcher if the great potential of computerization is to be realised. Experience in the U.S.A. suggests that researchers often fail to document their software adequately and rarely take any steps to ensure that field-workers are trained to use it properly.[3] Given the nature of computerization, anyone developing a worthwhile piece of software needs to assume the responsibility for documentation and training.

SCAB: A Computerized Management Aid for Sheep Enterprises

As already stated, although the principles involved could be applied to

[1] Portable terminals which may be connected to a computer via an ordinary telephone line are currently available for leasing at less than $200 per month.

[2] This list could be extended by including computerized accounting services such as those offered by the Farm Foundation of Western Australia, the Agricultural Business Research Institute at the University of New England and the Queensland Department of Primary Industries. (See Anderson [2] for details.) The recently published Bureau of Agricultural Economics beef model [11] also has potential as a computerized management aid.

[3] On this point see both Harrison and Rades [15] and Eisgruber [12].

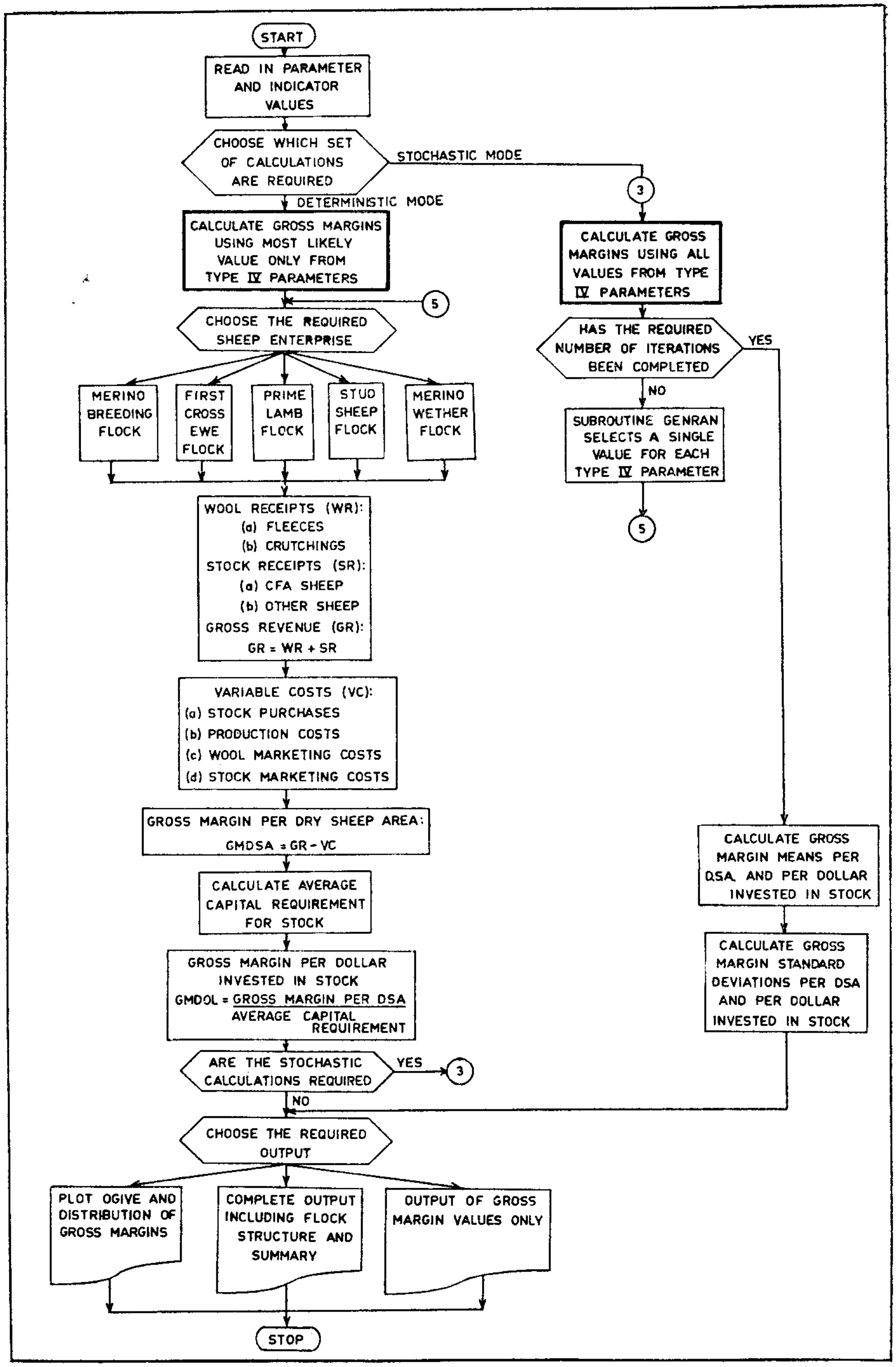

FIGURE 1: A Simplified Flow-chart of the SCAB Procedure.

any kind of farm enterprise, in the first instance the authors have developed SCAB for comparing sheep activities. For convenience and for programming reasons all feasible sheep activities have been grouped into five enterprises, namely merino breeding, merino wethers, first-cross lamb production, prime lamb production and stud breeding (see Figure 1).

The Basic Model

The basic approach underlying SCAB is the calculation of a gross margin defined as the difference between gross revenue and variable costs.[4] When gross margins are calculated by manual methods each of the costs and revenues are estimated at their average value (or modal value). On the basis of these point estimates, a corresponding point estimate is derived for the gross margin. Similar calculations are carried out for each of the activities under consideration and the activity with the highest gross margin is judged to be the most desirable. However, the desirability of any farm activity has at least two dimensions, the average (or the modal) pay-off and the risk or variability attached to that pay-off. SCAB not only computerizes activity budgeting using point estimates, but also provides a means of calculating the variability attached to the pay-off from each activity. SCAB, therefore, provides a second dimension to activity budgeting by calculating a measure of risk.

The FORTRAN IV program which is the basis of SCAB has been developed from a more detailed version of the Flow-chart in Figure 1. The cost and return parameters incorporated in the model and which determine the gross margin have all been grouped into one of the four categories shown in Table 1. As suggested by Table 1, the reasons for classifying the parameters in this manner were first, to facilitate writing the computer program and second, to clarify the collection of input data. Type I parameters are written into the program. Type II parameters may vary between geographic areas but one would not expect much variation between properties in any one district. Both Type III and IV parameters are expected to change from farm-to-farm.

The classification Type III includes parameters which are assumed to be deterministic for one of two rather different reasons. First, the value of the parameter may be known with comparative certainty and hence a point estimate is appropriate. Second, although the decision-maker is uncertain about the precise value of the parameter, the factor concerned is not very significant in the overall calculations. Therefore, as a simplification, these parameters are treated as if their values are known with certainty and they enter the calculations deterministically.

Type IV parameters are those which are both uncertain and impotant. It is the way SCAB handles these parameters which makes it a unique approach to measuring the two dimensions of an activity pay-off.

The Stochastic Component

Stochastic parameters are variables for which values are selected randomly from a probability distribution. In the light of the criteria

[4] The term 'gross margin' has a number of meanings. The conventional definition has been adopted for SCAB. (See Richards and McConnell [26]).

TABLE 1

Parameter Classification for the SCAB Computer Program

Parameter Type	Characteristics of Parameters	Examples
Type I	Deterministic. May *not* be altered by the user of the program at run-time. Written into FORTRAN IV executable statements.	Dry Sheep Equivalent factors. Ram shearing costs twice that of other adult sheep. Lamb drenching costs half that of adult sheep.
Type II	Deterministic. May be changed by the user at run-time. Values initialised by DATA statements. New values may be read in if required.[a]	Cost of dipping, vaccinating, wool packs, shearing, etc. Sale commissions.
Type III	Deterministic. Values must be supplied by the user. These point estimates are read in at run-time.[b]	Joining percentage. Number of jettings, crutchings, etc for year. Cost of casual labour, transport, etc.
Type IV	Stochastic. Values must be supplied by the user. Highest, lowest and most likely values are read in at run-time.[b]	Survival rates. Fleece weights. Lambing percentage. Stock Prices. Wool prices.

[a] An input schedule (Schedule A) has been prepared which both indicates the values assigned to all the Type II parameters by the DATA statements and provides a simple means of altering any or all of these point estimates if necessary.

[b] An input schedule (Schedule B) has also been developed to facilitate both the estimation of these values and their entry into the program.

suggested by Sprow [27], the triangular distribution was chosen in preference to other unimodal distributions such as the normal, the Beta and Poisson.[5] Of the two methods for defining a triangular density function from subjective estimates, the approach of Cassidy *et al.* [10] was chosen in preference to the technique suggested by Swirles and Lusztig [28] due to the directness and simplicity of the former. The Cassidy *et al.* approach provides a triangular distribution uniquely defined by estimates of the following three values for the variable under consideration: the lowest value anticipated; the most likely value; and the highest value anticipated.

An extension worker using SCAB would obtain the decision-maker's estimates of the lowest, most likely and highest anticipated values for each of the Type IV parameters. In this manner the subjective probability distributions of the decision-maker are incorporated directly into the SCAB calculations. The final measure of risk produced by SCAB, namely the variance of the gross margin, will, therefore, reflect the combined and appropriately weighted effects of the decision-maker's

[5] Cassidy *et al.* [10] compare and summarize the advantages and disadvantages of these distributions.

feelings about all of the important but uncertain relevant parameters.[6]

Using SCAB in the Field

The acceptance and effectiveness of SCAB (as with any computerized management aid) will depend heavily upon the ease of gathering the relevant data (the input schedules) and the clarity of the program output (the output schedules).

Two input schedules have been designed for SCAB. One to be completed by the district extension officer or management consultant (Schedule A) and a second to be filled in by the decision-maker (Schedule B)[7]. Input Schedule A allows the field worker to change any or all of the values in the program for the Type II parameters. Schedule B has been designed to obtain the manager's estimates of both Type III and Type IV parameters. In practice one would expect the field-worker to assist the manager in completing Input Schedule B.

Once the input schedules have been completed for one or more activities, the field worker must access the computer via a remote terminal and punch in the data on the input schedules.[8] The field worker must also indicate first, whether the SCAB program is to be run in the deterministic or the stochastic mode and second, whether a complete output schedule or a summary output schedule is required.

When SCAB is used in the deterministic mode the program calculates a single gross margin based on the single point-estimate submitted as the most likely value for each of the Type IV parameters. In this mode the program can be used to perform (or check) the traditional gross margin calculations[9]. The big advantage offered by SCAB over the usual pen-and-paper procedure is speed and accuracy. In addition, if one or more of the most likely parameter values need to be altered to judge the sensitivity of the gross margin to these parameters, the additional calculations can be performed speedily and accurately. This is rarely the case using manual methods.

Of course, the major feature of SCAB is the availability of the stochastic mode. As previously indicated, once the decision-maker has nominated his expectations for the important uncertain parameters, SCAB will generate a distribution of pay-offs and calculate the mean and variance of this distribution as measures of the two dimensions of the desirability of the activity. In the stochastic mode the program passes through the model 'n' times generating one gross margin at

[7] The input schedules are available from the authors.

[6] 'Appropriately weighted' means weighted according to the real economic significance of each parameter. Irrational over (or under) emphasis of one or two key variables frequently causes decision-makers relying only on heuristic (seat-of-the pants) procedures to make inappropriate assessments of the profitability of an activity.

[8] It would be feasible to post completed input schedules to a central processing facility. However, the delay between input and output together with the loss of the opportunity for subjecting the results to some sensitivity analysis, suggests that operating SCAB by post would reduce its usefulness.

[9] One immediate application of the SCAB approach would be to facilitate procedures of the kind recently reported by Blackburn [6] and by Blackburn, Frew and Mullaney [7]. The work of these authors could be extended by using SCAB in stochastic mode to generate a measure of risk.

each pass.[10] After 'n' iterations the mean and variance of the gross margins are calculated and the results for the activity being evaluated are printed out.

The complete output schedule involves a detailed description of the activity. It includes a listing of all the costs and returns involved in the calculations. In the case of the Type IV parameters the most likely values are printed out. In addition, the complete output schedules include a summary of the gross margin results. The summary output schedule consists only of this latter portion of the complete schedule. Normally the complete listing would be required only once for each activity. Thereafter as one or more of the input values were altered to test the sensitivity of the results, only the summary output would be required.

The form of the summary output depends upon the mode. Obviously, in deterministic mode there will only be one gross margin per dry sheep area and one gross margin per dollar invested for each set of input data. However, in stochastic mode the output consists of not only these two gross margins (based on the most likely parameter values) but also mean gross margins per dry sheep area and per dollar invested together with the associated standard deviations.

In addition to the above output schedules, when SCAB is used in the stochastic mode the field-worker may also call for a plot of both the gross margin distribution and the cumulative probability function or 'more than' ogive. To plot these functions it has been assumed that the distribution of gross margins generated by SCAB is normal. If the number of triangularly distributed variables which enter the calculations stochastically is large, the Central Limit Theorem may justify this assumption.

Problems and Extensions

The most serious problem or limitation with the conceptual framework underlying SCAB is the assumption of zero covariance between the stochastic parameters. For instance, one would expect high death rates due to drought say, to be frequently associated with low wool cuts and low lambing percentages. Since the model does not currently allow for any correlation between these parameters, it is possible for the negative economic effect of high death rates to be offset by high wool cuts and/or high lambing percentages far more often than one would expect in reality. SCAB, therefore, will provide a measure of risk which is biased downwards. The model could be extended to incorporate some inter-correlations between key parameters. However, it is difficult to obtain data from which to calculate the extent of these inter-correlations.[11]

[10] The stability of the resulting distribution depends on the value assigned to 'n' In most cases '$n = 100$' would be an appropriate choice. Although computing charges vary a great deal, the computer time required to obtain a complete output schedule is unlikely to cost more than $2 (with $n = 100$).

[11] Even if inter-correlation values could be calculated, the problem of whether to include them in the model as Type II, III or IV parameters would still remain. It has been suggested (P. F. Byrne, private communication) that since certain key stochastic parameters are likely to be significantly correlated, it would be preferable to assume perfect correlation rather than zero covariance. In this case the measure of risk would be biased upwards.

The authors have taken the view that on *a priori* grounds one would expect the direction and degree of bias to be of the same order of magnitude for most feasible sheep activities on any given property. Therefore, if the objective is to rank sheep activities according to their riskiness, the current bias in SCAB may not be important. Nevertheless SCAB highlights the need for further researeh into the extent and the economic significance of the inter-correlation between parameters which have an important influence on activity outcomes.

Another potentially serious limitation with SCAB is that all the stochastic parameters are assumed to be triangularly distributed. This may seriously distort the 'true' subjective probability distribution under consideration.[12] A solution to this problem would be to allow the manager to estimate the shape of his subjective probability distribution for each key parameter with marbles or some other counter technique. (See, for example, Barnett [4] and Francisco and Anderson [14]). This kind of detail could only be justified for the most important parameters such as wool prices, survival rate of ewes and fleece weights.

Since the model is currently an annual one, it does not explicitly allow for changes in the time of shearing nor does it incorporate many other details one could add if the model were based on a monthly time period. It does, however, implicitly permit certain time-dependent management factors to be incorporated. For example, autumn and spring lambing can be compared by nominating different lambing percentages, ewe survival rates, etc. There seems little justification for greatly increasing the complexity of SCAB by moving to a model which considers time periods of less than one year.

SCAB is data generating and does not make the decision for the manager. SCAB only calculates the implications of his expectations and summarizes these implications in terms of the mean and variance of the gross margin for each of the activities he wishes to consider. The final decision as to how to trade riskiness against a higher mean pay-off is left to the manager. However, if the field-worker could obtain an estimate of the manager's utility function, the field-worker may be able to advise the decision-maker as to which of the activities he should prefer if he is to act in a manner consistent with his utility function [23].[13] In the absence of a utility function, the concept of stochastic dominance recently discussed by Anderson [1] may help the field-worker to ensure that a manager using SCAB does not make an irrational choice as between alternative risky prospects (activities).[14]

In time the authors hope to extend SCAB to other livestock enterprises and to crops. If SCAB could be applied to all feasible activities on a given farm it would be a relatively simple step to modify the program so that it also calculated co-variances between activity pay-offs. Once

[12] The triangular distribution is also particularly restrictive in that stochastic interdependencies other than zero or perfect correlation cannot be readily accommodated. (The authors wish to thank an anonymous referee for drawing their attention to this point.)

[13] The possible combination of SCAB and utility analysis highlights a frequently overlooked theoretical point. SCAB allows only for the variable costs associated with each activity. When the objective is to maximize utility, overhead (fixed) costs are also relevant. For example, see McArthur and Dillon [22, pp. 20-21].

[14] As suggested by an anonymous referee, a sub-routine could be added to the SCAB program to rank activities according to stochastic dominance rules.

this kind of information was available it would be possible to either apply simple diversification criteria such as that suggested by Heady [17, pp. 510-521] or more sophisticated methodologies such as portfolio analysis [13], risk constrained Monte Carlo budgeting and Stochastic Programming [25, 29]. In fact, if the general SCAB procedure was coupled to a matrix generating routine, the data input for SCAB could lead directly to both the construction of matrices and the derivation of optimum farm plans using the most advanced planning methodologies.

The potential of SCAB for educational purposes has already been demonstrated. Students playing the Central Tablelands Farm Management Game [20] at the University of Queensland during 1974 used SCAB to analyse their sheep activities. This experiment indicated that SCAB can provide an excellent introduction to EDP and computers in general. There would appear to be a role for SCAB in adult education and extension courses in rural areas. SCAB provides a readily understood application of modern computer technology to solving a problem of relevance to rural adults. In this way SCAB could be used to break down the 'black box' syndrome and help people to gain confidence in the use of computers.

Concluding Comments

The managers of Australian agricultural firms have not yet begun to utilize the modern EDP techniques which have revolutionized management in other sectors of the economy. Computerized management aids such as SCAB have a potential for increasing the efficiency and rationality of farm decision-making. Perhaps even more importantly, they have a potential to increase the effectiveness of existing extension man-power and other extension resources. A computerized package such as SCAB could be taken to farms by using an inexpensive portable terminal and telephone coupling device (to obtain remote access to the computer which may be hundreds of miles away). The computerized management aid would then become the focus for dialogue between the farmer and the extension agent. Seen in this light computerized management aids may be able to contribute significantly to improving the efficiency and productivity of extension personnel. However, this potential will only be realized if the authorities responsible for agricultural extension services are far-sighted enough to provide their officers with the appropriate training and hardware facilities.

References

[1] Anderson, J. R., 'Risk Efficiency in the Interpretation of Agricultural Production Research', *Review of Marketing and Agricultural Economics*, Vol. 42, No. 3 (September, 1974), pp. 131-184.

[2] Anderson, K. *Farm Management Information Systems in Australia and their Relevance to South Australia* (South Australian Department of Agriculture, Extension Branch Report, October 1971).

[3] Angus, J. F., I. M. Wood, and K. D. Cocks, *Budget: A Program for Estimating the Cost of Production and Profitability of Crops* (Commonwealth Scientific and Industrial Research Organization, Division of Land Research, Canberra, Technical Memorandum 73/4, March 1973).

[4] Barnett, R. L., 'Information for Farm Management Decision Making: An Outline of a Theory of Information Use in Agriculture Together with a Suggested Format for an Information System' (Unpublished Master's thesis, University of New England, Armidale, October 1969).

[5] Bayley, N. D., *Computer Use in Farm Management Analysis and Production Decisions* (Proceedings of a Workshop, United States Department of Agriculture, Washington, D.C., November 20-22 1968).

[6] Blackburn, A. G., *Sheep Budgeting Made Simple* (Victorian Department of Agriculture, Sheep Industry Branch, August 1972).

[7] Blackburn, A. G., M. V. Frew, and P. D. Mullaney, 'Estimating Optimum Stocking Rates for Wethers', *Journal of Australian Institute of Agricultural Science*, Vol. 39, No. 1 (March, 1973), pp. 18-24.

[8] Byrne, P. F., 'Parametric Budgeting using a Model of the Sheep Enterprise', *Review of Marketing and Agricultural Economics*, Vol. 32, No. 3 (September 1964), pp. 95-136.

[9] Candler, W., M. Boehlje, and R. Saathoff, 'Computer Software for Farm Management Extension', *American Journal of Agricultural Economics*, Vol. 52, No. 1 (February 1970), pp. 71-80.

[10] Cassidy, P. A., J. L. Rogers, and W. O. McCarthy, 'A Simulation Approach to Risk Assessment in Investment Analysis', *Review of Marketing and Agricultural Economics*, Vol. 38, No. 1 (March 1970), pp. 3-25.

[11] Cottingham, I. R., *et al. A Computer Model Simulating Extensive Beef Cattle Production Systems* (Australian Bureau of Agricultural Economics, Canberra, Occasional Paper No. 21, April 1974).

[12] Eisgruber, L. M., 'Managerial Information and Decision Systems in the U.S.A.: Historical Developments, Current Status, and Major Issues', *American Journal of Agricultural Economics*, Vol. 55, No. 5 (December 1973), pp. 930-937.

[13] Francis, J. C., and S. H. Archer, *Portfolio Analysis* (Englewood Cliffs: Prentice-Hall, Inc., 1971).

[14] Francisco, L. M., and J. R. Anderson, 'Chance and Choice West of the Darling', *Australian Journal of Agricultural Economics*, Vol. 16, No. 2 (August 1972), pp. 82-93.

[15] Harrison, G. A., and R. J. Rades, 'Delivery Systems for Computerised Farm Management Aids in Extension: Opportunities and Challenges' (A paper presented at Joint Meeting American Agricultural Economics Association, Canadian Agricultural Economics Association, Western Agricultural Economics Association at Edmonton, Alberta, Canada, August 8-11 1973). Mimeo.

[16] Harrison, S. R., *A Manual of Computer Programs.* (Queensland Department of Primary Industries, Economic Services Branch, July 1970).

[17] Heady, E. O., *Economics of Agricultural Production and Resource Use* (Englewood Cliffs: Prentice-Hall, Inc., 1961).

[18] Lanpher, B. F., *Inventory of E.D.P. Programs and Facilities: 2nd Edition, Used in Extension Farm Management Programs* (Federal Extension Service, United States Department of Agriculture, Washington, D.C., 1968).

[19] ———, *Inventory of E.D.P. Programs: Used in Agricultural Extension* (Federal Extension Service, United States Department of Agriculture, Washington, D.C., May 1973).

[20] Longworth, J. W., *The Central Tablelands Farm Management Game: Manual for Participants* (University of Queensland, Department of Agriculture, St. Lucia, 1973).

[21] McAulay, T. G., *Simulation as an Aid to Decision Making* (University of Guelph, School of Agicultural Economics and Extension Education, Working Paper AE/72/17).

[22] McArthur, I. D., and J. L. Dillon, 'Risk, Utility and Stocking Rate', *Australian Journal of Agricultural Economics*, Vol. 15, No. 1 (April 1971), pp. 20-35.

[23] Officer, R. R., A. N. Halter, and J. L. Dillon, 'Risk, Utility and the Palatability of Extension Advice to Farmer Groups', *Australian Journal of Agricultural Economics*, Vol. 11, No. 2 (December 1969), pp. 171-183.

[24] Officer, R. R., and J. L. Dillon, *Calculating the Best-Bet Fodder Reserve.* (University of New England, Professional Farm Management Guidebook No. 1, 1965).

[25] Rae, A. N., 'Stochastic Programming, Utility, and Sequential Decision Problems in Farm Management', *American Journal of Agricultural Economics*, Vol. 53, No. 3 (August 1971), pp. 448-460.

[26] Rickards, P. A., and D. J. McConnell, *Budgeting, Gross Margins, and Programming for Farm Planning* (University of New England, Professional Farm Management Guidebook No. 3, 1968).

[27] Sprow, F. B., 'Evaluation of Research Expenditure Using Triangular Distribution Functions and Monte Carlo Methods', *Journal of Industrial and Engineering Chemistry*, Vol. 59, No. 7 (July 1967), pp. 35-38.

[28] Swirles, J., and L. A. Lusztig, 'Capital Expenditure Decisions under Uncertainty', *Cost and Management*, Vol. 42, No. 8 (September 1968), pp. 13-19.

[29] Trebeck, D. B., and J. B. Hardaker, 'The Integrated Use of Simulation and Stochastic Programming for Whole Farm Planning under Risk', *Australian Journal of Agricultural Economics*, Vol. 16, No. 2 (August 1972), pp. 115-126.

[30] Walker, H. W., *Current Use and Immediate Potential of Remote Terminals in Extension Programs* (Proceedings of Seminar, Virginia Polytechnic Institute and State University, Blackburg, Virginia, December 7-9, 1971).