A DECISION-THEORETIC APPROACH TO THE PLANNING OF AGRICULTURAL EXTENSION

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PETER MUNRO GAULT

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ABSTRACT

The extension agency, faced with the need to make more effective use of its resources, requires information about the value of the alternative extension messages which it expects will assist farmers to increase net income. It is hypothesised that Bernoullian decision theory is applicable to the extension agency's problem by helping it to assess the expected value of the increases in aggregate farm incomes following extension.

An extension message is seen as assisting farmers to make decisions and thereby increasing expected income. Where the extension information is aimed at helping the farmer estimate the occurrence of the uncertain events in a decision problem, Bayes' theorem provides the basis for a method of obtaining the value of the information. An extension message can also assist by helping to analyse the decision problem or by providing information about some new or innovative course of action for solving the problem.

The difficulty encountered by most published methods for evaluating agricultural extension is that of determining the proportion of the change in farm income due to extension and that due to other factors which are also affecting farm income. The method outlined in this thesis relies on a preposterior estimate of the value of an extension message which largely overcomes the problem of estimating the without-advice situation.

A start was made on testing the proposed method by obtaining information from several dairy farmers about specific decision problems, the alternative courses of action and the other details that would enable a model of the decision problems to be synthesised. Because of the difficulty of obtaining that information, and of developing an adequate model of a problem, the attempted application was reduced to one farmer and the particular problem of summer-feeding of the herd.

Summer rainfall, pasture growth, milkfat output and milkfat price were the sources of uncertainty which were incorporated into the decision model. The analysis indicated only limited potential for additional information to assist the farmer with the decision problem. The research provided some support for the hypothesis since it was found to be possible to simulate a farmer's decision problem under uncertainty and to obtain a pre-posterior estimate of the farmer's expected income without advice.

PREFACE

An extension agency, such as the Advisory Services Division of the Ministry of Agriculture and Fisheries, is faced with decisions of how to allocate its scarce resources in order to assist its clients to achieve their objectives. To assist with this problem the Ministry of Agriculture and Fisheries established a research fellowship in co-operation with Massey University. Part of the research by the first fellow, Mr J.D. Squire, was to describe a model for planning agricultural extension.

The research presented in this thesis was undertaken during the author's tenure of the fellowship and it is an attempt to tackle one of the first steps of the planning process; the question of how to evaluate the alternative extension messages to which the agency can allocate its resources?

The first chapter introduces the problem in the context of the process of agricultural extension, defines the basic research hypothesis and the goals of the extension agency. In chapter two there is a brief discussion of the ways in which extension can affect its clients' decisions and a review of some of the methods which have been proposed for the evaluation of agricultural extension. In chapter three the theoretical basis of the proposed method is outlined and chapter four reports on an attempt to apply the method in the context of a dairy farmer's decision problem of how to farm with the possibility of a dry summer. The final chapter includes the summary, conclusions from the research and some discussion of the problems which have arisen and their possible solutions.

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1. INTRODUCTION TO THE PROBLEM AND THE RESEARCH

1.0 INTRODUCTION

The Advisory Services Division of the Ministry of Agriculture and Fisheries (MAF) employs the equivalent of half of the full time agricultural extension workers in New Zealand (Squire and Hughes, 1973). As part of an effort to improve the effectiveness of its extension service, the MAF provided the author with the opportunity to carry out a research project into agricultural extension under the supervision of Mr A.H. Hughes, a senior lecturer in agricultural extension at Massey University.

The author chose to further some research which was commenced by Mr J.D. Squire, who was the previous (and first) advisory officer to be appointed to the research fellowship. In his tenure of the fellowship Mr Squire described what was termed the 'advisory process' which was suggested, together with the communication and adoption/diffusion processes, as a natural division of the extension process (Squire and Hughes, ibid).

This description of the advisory process, which was also presented diagrammatically and called the Massey Advisory Model, was an outline of the activities which an extension agency, or its agent, should be carrying out in order to fulfill its extension role. These activities include defining objectives and planning, implementing and evaluating the work required to attain the objectives.

Squire and Hughes (ibid) summarise the efforts of Raudabaugh (1956), Maunder (1956), Parkin (1972) and Dale et al (1972) to develop what might be termed a descriptive model of the extension process.

All these models, including the Massey Advisory Model, have arisen out of the application of the decision-making or management process (Hodgson, 1971) to the work of agricultural extension. The purpose of the models is largely descriptive. They are an attempt to outline all the components of the process which an extension agent should be involved with in the organisation of his work.

But Squire and Hughes (ibid) also note the applicability of the comments of Engel et al (1968) who point out that models in the field of consumer behaviour are at the stage of relatively unsophisticated flow charts. Likewise, in the field of agricultural extension there has been little attempt to provide a theoretical or empirical solution to the problems which arise in an application of these models of the extension process.

Accordingly, Squires (unpubl.) on completion of his term as research fellow recommended that there be an attempt to apply the proposed model and thereby test its validity.

Also, it was suggested by Mr W.R. Dale, an extension specialist with MAF, that one of the most important areas for research in agricultural extension was the requirement to 'refine the methodology of selection and expression of objectives' (MAF unpubl.).

1.1 THE CONTEXT OF THE PROBLEM

The author's first attempt to investigate the Massey Advisory Model, was to apply a method suggested in the 'planning decision phase'. The purpose of this phase was to develop a list of the alternatives to which the extension agency might allocate its resources. As Lindley (1971) points out, the first task in any decision problem is to draw up a list of the possible actions that are available.'

The first step in the model is to describe the components of the agricultural systems within the area of interest and this is termed the 'actual situation'.

In models of Parkin (ibid) and Dale et al (ibid) this step is called the 'situation analysis.'

The author found that it was possible to obtain a considerable amount of information about a proportion of the farms and farming systems of a district from other extension workers and servicing personnel such as the Dairy Board Consulting Officer and the Farm Dairy Instructor with MAF.

The next step in the Massey Advisory Model was to "identify and document the full range of possible farm management systems ...... and list the resources needed for each of these systems". Then the model suggested that a comparison be made between the 'actual' and 'possible' situation. The differences which showed up as a result of this comparison would be potential areas of work for the extension service.

The author did not attempt to implement this step of the model which required information which would identify the optimum combination of resources for a district. This normative type of study did not appear to be within the scope and resources of the research project.

An alternative to an attempt to document the theoretically possible situation would be a case study approach, in which a proportion of farmers who were regarded as top 'farmers (in some sense) would be studied to document the 'possible' situation.

The stages of the advisory process discussed so far are aimed at developing a list of the alternatives to which the extension resources might be allocated. An alternative approach to the compilation of this list would be to assume that the extension agency was already aware of a list of extension messages which were expected to benefit its clients.

The problem for the agency, rather than one of developing the list of alternatives, now becomes one of deciding what proportion of its resources it should allocate to each of these alternatives. It was this problem of choosing the priorities from a list of alternatives, rather than developing the list, which the author chose as the basis of the research.

However the problem of developing the list of alternatives still exists for the extension agency and some comments by Lindley (ibid) are pertinent to the problem.

> 'Considerable attention should be paid to the compilation of this list because the choices of action will be limited to those contained in it ..... Often one cannot be sure that some attractive possibility has not been omitted: there is always the chance that some ingenious person will come along with a proposal that the decision-maker has not considered. It is almost certainly true that some successful decision-makers derive their success from their ability to think of new ideas, rather than from any ability to select amongst a list .... we can offer no scientific advice as to how it is to be developed'.

1.2 THE HYPOTHESIS

The problem for the extension agency is to allocate its resources to the alternative extension messages in order to achieve its goal.

Several researchers have shown Bernoullian (1) decision theory to be of some value in assisting farmers to make decisions about the reallocation of resources with advantage to themselves.

Carlson (1970) applied the theory to the pesticide application practices of California peach growers in treating peach brown rot and derived improved practices for the use of pesticides.

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(1) A descriptive label for the theory suggested by Dillon (1971) and based on Bernoulli's original work on the theory.

He concluded that the theory appears to be applicable when disease control costs are high relative to product price, when the intensity of damage is highly variable from year to year and when epidemics can be predicted with some reliability.

In another horticultural application, Rae (1971) used a discrete stochastic programming procedure to obtain the optimal combination of vegetable crops for a grower faced with uncertain weather and market prices. The model of the problem took account of the sequential nature of the decisions and the grower was shown to be better off, in terms of expected utility, from the optimal strategy compared to that of the deterministic strategy.

The extension agencies, in their role of assisting farmers with the reallocation of resources, also have a resource allocation problem. Their problem of what extension to give, how to give it, and to whom to give it, has been researched less intensively than the farmer's problem of how to make use of extension information.

The hypothesis is that Bernoullian decision theory is applicable to the resource allocation problem.

The agency has:
- a list of alternative extension messages;
- potential or actual clients;
- resources, e.g. extension personnel;
- insufficient resources to provide all the extension messages to all the clients

Therefore a resource allocation problem exists.

The agency must decide:
- which messages are to be conveyed;
- to which clients they are to be directed;
- which resources are going to be allocated to the various

message/client combinations

1.3 THE GOALS OF THE EXTENSION AGENCY

The variety of factors that have a bearing on the goals of the extension agency is suggested by the following excerpt from a document prepared by OECD.

> The best objectives in theory are those reconciling the individual objectives of farmers, the common objectives of certain communities or categories of agricultural producers, the objectives of agricultural, regional and national policy and the specific objectives of the advisory services. All these objectives are interdependent, sometimes conflicting and must be more or less systematically weighted by the agricultural advisory authorities (OECD, 1974).

An Advisory Services Division circular which outlines the job responsibilities for advisory officers (unpubl.) requires them to assist farmers to achieve the attainable agricultural potential of the district within the limits of "farmers' aspirations and economic well-being".

An example of the conflict between the nation's and the individual farmers' goals is shown by Cartwright (1967) to result from the effect of N.Z. income tax laws.

We can distinguish two types of extension agency, the public, e.g. the Advisory Services Division of MAF, and the private. For the former, the goal might be to make extension decisions so as to maximise the net addition to social welfare due to extension activities.

In practice, this could be approximated through estimating the expected value and variance of the present value of the increases in aggregate farm incomes following extension. However, non-financial factors, such as providing easier, or more varied working conditions should not be forgotten.

An important goal of the private extension agency is, no doubt, the maximisation of profit. Since the fee charged by this type of agency is likely to depend upon the expected value of the advice to the client, then the increase in aggregate farm income due to their extension activities could still be an appropriate measure of worth to the agency.

Thus we can define the agency's goal as to maximise the present value of the change in aggregate farm income subject to available resources and knowledge.

1.4 THE NATURE OF THE EXTENSION MESSAGE

The list of alternatives which have been mentioned above, are information messages which the extension agency expects will assist farmers with their decision problems. The ways in which additional information about a decision problem can assist the farmer are discussed in the next chapter.

In the Massey Advisory Model the extension agency's list of alternatives are basically husbandry or management practices that will assist farmers to move from the 'actual' to the 'possible' situation. But they are redefined in terms of 'behavourial changes' since, as suggested by Squire and Hughes, these must accompany changes to farmers' decision problems.

But while 'changes in human resources' e.g. farmers' knowledge, skill and attitudes, must occur for there to be changes to farmers' decisions, the goals of the agency are best expressed in the same terms as the dimensions of farmers' goals, e.g. farm income. After all, it is by assisting farmers to achieve their goals not change their behaviour that the extension agency fulfills its purpose.

1.5 SUMMARY

The extension agency's problem of how to evaluate the alternative information messages is outlined as the basis of the research objective and this problem is related to previous research on models of the extension process. The goals of the extension agency and the nature of the extension message are outlined.

2. THE EFFECTS AND THE VALUE OF EXTENSION

2.0 INTRODUCTION

The purpose of the extension agency is to maximise the present value of the change in aggregate farm income due to extension activities. Any change in aggregate farm income is going to depend, in part, on the value of an extension message to the individual farmers to whom the message is directed. The other important determinant of the aggregate value of an extension message is the number of farms or farmers who are affected by it.

This chapter outlines the ways in which an extension message might assist the individual farmer and reviews some of the methods for measuring the value of extension which have been reported in the literature.

2.1 THE EFFECT OF EXTENSION

There seems to be a general acceptance in the literature that extension assists farmers to make decisions, e.g. Routhe (1962), Avery (1971), Squire and Hughes (1973). Therefore a study of the decision-making process should help to assess the way an extension agency could assist its clients.

Bernoullian decision theory has been proposed as a model of the decision-making behaviour of farmers and there are several research studies which give some support to this proposal. Officer and Halter (1968), in the context of a fodder reserve problem, showed that farmers' operational decisions are more consistent with a criterion of maximising expected utility than with the criterion of maximising expected profit. They noted that over the period of a year the farmer's decisions on fodder reserves, as well as their utility functions, did not change radically.

McArthur and Dillon (1971) used a decision theory-based model of wool production to show that a conservative stocking rate was consistent with the preferences of risk-averse farmers. The authors pointed out that this allocation of resources will be suboptimal relative to that implied by expected profit maximisation which is likely to be the national point of view.

In a study intended by the authors, Lin et al (1974), to complement the work of Officer and Halter (ibid) by extending the analysis to large-scale Californian farms, it was shown that Bernoullian decision theory was a better prediction of actual and planned decisions than profit maximisation. The authors also suggested that better predictions of aggregate behaviour would result from concentrating on aggregating farms with similar utility functions, which is a suggestion that is relevant to any attempt at planning agricultural extension for a community of producers.

Based on the premise that Bernoullian decision theory is an adequate model of the decision process, the following is a discussion of how an extension agency might assist its clients to make decisions.

2.1.1 Decision Analysis

The extension agent can help with the process of analysing a decision problem for the farmer, using the farmer's information about the alternative solutions and their consequences and the farmer's utility for the consequences. The extension agent is acting as a 'decision analyst' (Raiffa 1968).

The need for this assistance is indicated, for example, by the finding of Officer and Halter (1968) that farmers can be inconsistent when making simple decisions about the level of fodder reserves and the authors' recommendation for the use of decision theory as an aid to complex decision making.

This way of assisting a farmer, by applying 'some guidelines for sensible decision making' (Lindley, 1971) to obtain the farmer's best course of action, is more in line with the role of a supervisor than an extension worker. (1)

Rather than helping the farmer to find the best decision to a particular problem the extension agent's real role is to demonstrate the use of a decision theory model which the farmer can then apply to other problems without relying on the extension agent. So, for example, Routhe (ibid) suggests that 'the central educational objective (of extension) should be to help rural people to improve their ability to make decisions ....'.

Likewise Campbell (1962) in a paper to an Australian Agricultural Extension Conference suggests that 'in a world where nothing is more certain than the certainty of change, it is important to place emphasis in all phases of education upon thought processes rather than on particularised subject matter'.

2.1.2 New Alternatives

Another way that an extension agency may assist its clients is to provide information of an alternative and innovative solution to a decision problem. The agency expects that some 'new' course of action (to the farmer) will be more profitable

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(1) The supervisor makes the decisions and supervises their implementation; the extension worker aids the farmer in making decisions (Squire and Hughes, ibid).

than any of the farmer's original alternatives and therefore the farmer should adopt the change.

According to Dillon (1971), this type of advice, which he describes as the addition of further acts to the pay-off table, is a major role of agricultural consultants.

2.1.3 The Revision of Uncertainty

An essential element of the Bernoullian model is the decision-maker's beliefs about the occurrence of uncertain events and their expression as probabilities. The difficulty of making a decision is due, in part, to the influence of uncertain events on the decision and the extension agency may assist the farmer by providing information about their occurrence. Any additional data about the uncertainty will help the farmer with his choice.

The way in which additional information about the uncertain events should be incorporated into the decision problem is given by Bayes' theorem and is widely described in the literature e.g. Dillon (ibid). The expected value of this information to the farmer can also be obtained. It is this well-defined theory for making a preposterior estimate of the value of the information which seems to justify an investigation of its applicability to the extension agency's problem.

Farmers are obviously faced with various sources of uncertainty, e.g. climatic, pest and disease, market, technical uncertainties, and it seems likely that to a large extent their need for advice is a result of the uncertain environment and its effect on their decisions.

It is the complex nature of farming systems with all its uncertainties which Hodgson (pers. comm) suggests has required an extension service to be made available to farmers.

If, as Lindley (ibid) suggests, Bayes' theorem describes how most adult learning occurs, and since the extension agency is attempting to influence this process, then the effect of extension messages should be considered in the context of Bayes' theorem.

Since the effect of agricultural extension is to assist farmers to make decisions, the foregoing has looked at several parts of the decision process where it is thought that an extension message may have an influence. Basically there are two ways in which an extension message can affect a farmer's decisions. First, by revising his payoff matrix; which can occur through the addition of further (new) alternatives or by helping to reassess the consequences of the alternatives, or by the addition or refinement of the uncertain events. Secondly, by providing additional information about the probability of occurrence of the uncertain events. Therefore, any attempt to evaluate an extension message should take account of the several ways that the information can assist farmers.

2.2 METHODS OF MEASURING THE EFFECT OF EXTENSION

The research objective is to develop a method which will assist an extension agency to assess the value of an extension message to individual farmers. More information about the value of alternative messages will help the agency with its decision of how to allocate its resources. The emphasis is on a preposterior analysis of the value of extension messages in order to assist the agency with its planning.

However, the value of an extension message will also depend on the input of extension resources, i.e. the intensity of the extension effort. This relationship between extension intensity and benefits, for a message, I_k, might be similar to that shown in figure 2.1. Increased expenditure by the extension service on the message, I_k, will increase the value of that information as, for example, more farmers are made aware of it, and use it in helping to solve their decision problem.

In a discussion of this question of the optimal intensity of extension, Ruthenberg (1974) points out that the optimal intensity of extension is attained when the marginal return on each dollar in different projects is the same. He defines the marginal return as the present value of the stream of returns caused by the last unit of extension expenditure. He also says that empirical investigations of the marginal returns from extension expenditure are practically non-existent.

However, there have been several attempts to make an _ex post_ analysis of the benefits of agricultural extension and which have been reported in the literature, e.g. Lever (1970), Squire and Hughes (1973), Hughes _et al_ (1973). Because of the _ex post_ nature of these analyses there has been a problem of how to partition the change due to extension and that due to other factors operating in the particular situation.

Many of the proposed solutions to this problem have been based on a study by Griliches (1960) of the spread of hybrid corn. He showed that it followed an s-shaped curve over time, the so called 'growth' curve, and he pointed out that this pattern of technical change in agriculture was a convenient way of summarising three major characteristics of a diffusion pattern, the date of beginning, relative speed and final level. For example, Griliches compared the rate of acceptance of hybrid corn in various corn growing areas of

FIGURE 2.1 EFFECT OF EXTENSION INTENSITY ON THE VALUE OF AN EXTENSION MESSAGE

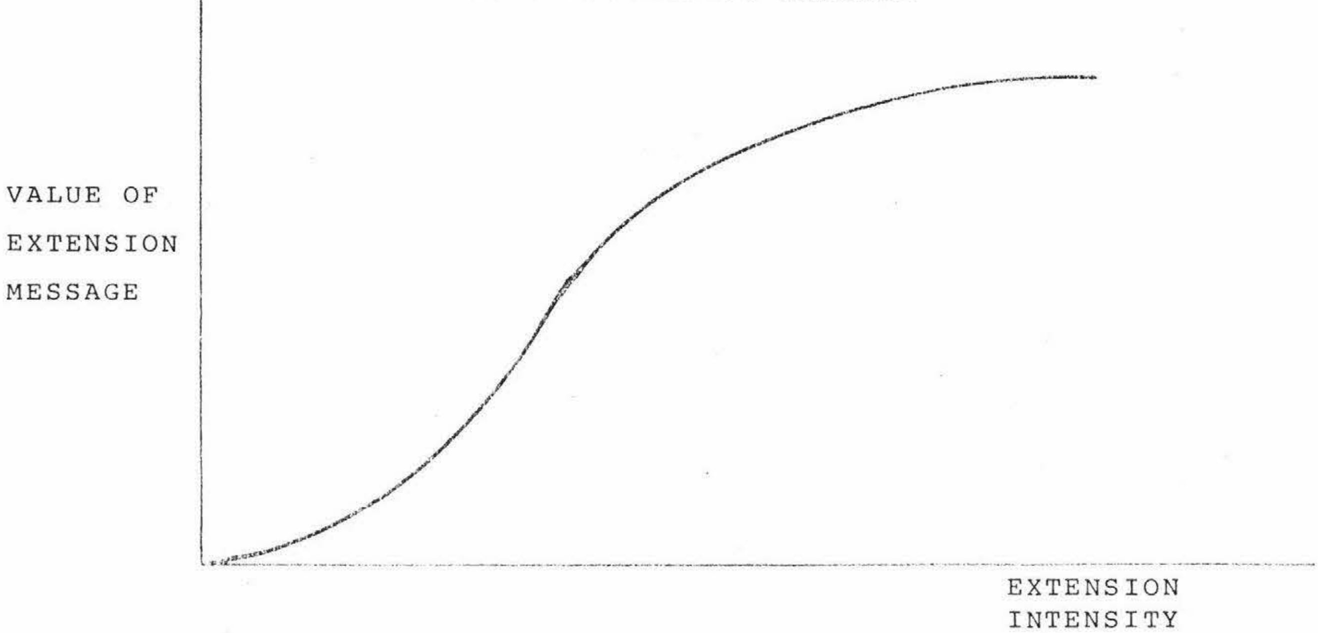
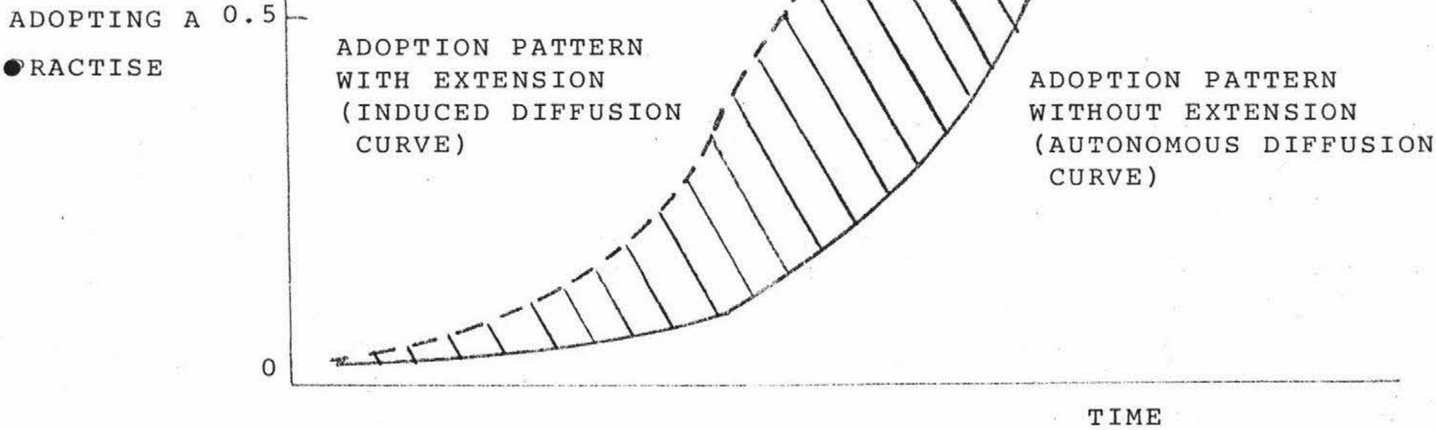


FIGURE 2.2 EFFECT OF EXTENSION ON THE ADOPTION PATTERN (LEVER, 1970)



the United States on the basis of differences in the slope of the diffusion curve. He attributed the slower rate of acceptance in some areas to the lower yield increases from hybrid corn and the consequent lower profitability.

2.2.1 Diffusion of Technical Change

Lever (ibid) in a study of agricultural extension in Botswana, used the model of the diffusion of technical change as proposed by Griliches (ibid) as the basis for the evaluation. Lever suggested that the effect of extension may be envisaged as increasing the propensity of farmers to use particular techniques resulting in an upward shift of the adoption curve (Fig. 2.2) (3).

Data from a farm management survey by Lever produced a significant regression relationship between gross output and extension. Further analysis linked the extension effect with farm implement investment.

Lever also attempted a cost benefit analysis of extension. He included in the costs of the extension service, the costs of training the extension workers at the agricultural college as well as other variable costs, e.g. salaries, travelling expenses and a proportion of administration and headquarters costs.

Based on these costs, he produced a breakeven budget for arable extension with an estimate of the benefit required to 'justify' extension effort.

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(3) The adoption curve and the nature of the relationship suggested in figure 2.1 are very similar. This follows from the similarity of the variables in the two relationships. The adoption curve measures the value of extension in terms of the number of farmers adopting a technical change. The number of years spent in passing on the change is a measure of the input of extension resources i.e. the extension intensity.

In calculating the benefits of the particular extension scheme, Lever considered that a diffusion effect was virtually negligible, since farmers outide the extension scheme concurrently had a very low rate of purchase of farm implements which was the key innovation in the extension package. Therefore all the change was attributed to extension which side stepped the problem of deciding how much change was due to advice.

Ruthenberg (1975) used the model developed by Lever as the basis for his proposals for evaluating the economic benefits of extension in connection with the rice programme in the highlands of Madagascar. The area between the autonomous and the induced diffusion curve was a measure of the returns from agricultural extension. The autonomous diffusion curve measured the acceptance of an innovation by farmers that would have occurred, without any public extension expenditure. The number of farmers who practised an innovation, or the area cultivated with a new crop, were examples of a measure of the diffusion of an innovation.

The induced diffusion curve was the total number of farmers or the total area of new crop when there was public expenditure on extension.

Ruthenberg did not test his proposals empirically but suggested that the benefits of the increased diffusion rate be valued by finding the net returns achieved by each innovator through applying the innovation. He admitted that it would be very difficult to estimate these figures but said it should be possible for the experienced development economist, on the basis of experience and ex post analyses, to give a rough idea of the size of the induced production increase.

All Ruthenberg's proposals were aimed at assisting with a comparison between investment in agricultural extension and other forms of capital investment. One of the questions he tackled was that of the optimal timing of the reduction or conclusion of an extension project. He suggested the use of decision making trees to grade projects on the degree of farmer adherence to an innovation over time. The example he gave showed how two projects may have the same adoption rate in the first year but because a larger proportion rejected the innovation in subsequent years, it was necessary to continue extension on this project for a longer period of time.

This use of decision making trees is similar to the 'innovation use tree' (Rogers 1962) which is a historical description of shifts between adoption and discontinuance of ideas over time which was used in a study by Coughenour (1961). As Rogers pointed out, "it might be possible that the extent of disenchantment with an idea might be predicted just as the rate of adoption of an innovation might be estimated in advance."

Squire and Hughes (ibid) have discussed the problem of measuring the effect of advice and particularly the difficulty of estimating the proportion of an observed change which is attributable to extension. They have provided a table, based on their intuition, giving the proportion of change which may be attributable to advice depending on the type of change and way in which it is measured.

In an evaluation of the advisory effort directed towards all grass wintering of stock in Southland, Squire and Hughes used a method similar to Lever (ibid) for quantifying the benefits of extension. They surveyed 500 Southland farmers (15% of the population) and observed the number of farmers who had adopted or were intending to adopt this method of all grass rotational winter grazing for sheep.

Their estimate of the benefit to farmers of adopting this innovation was based on the difference in the average per acre gross margin between farms that had and had not adopted. It was assumed that the farm gross margin of the "traditional" winter crop system would have been the return if farmers had not adopted the innovation.

Presumably, when the authors decided on the proportion of the payoff from the innovation which was due to the extension programme, they referred to the table mentioned above. In any case, an arbitrary 20% of the value of the innovation was attributed to the advice given to Southland farmers about all grass wintering.

These three attempts to evaluate agricultural extension assessed the benefits of extension in terms of changes to the rate of diffusion. In order to define the situation which might have occurred without an extension programme, i.e. the autonomous diffusion curve, Squire and Hughes surveyed farmers who had not adopted, Ruthenberg, suggested that it should be possible to estimate the situation without advice and Lever was able to ignore it altogether.

In a different approach to the problem Hughes et al (1973) in an evaluation of the Cronin Pilot Advisory Scheme carried out surveys before and after a period of three years advice to low producing dairy farmers to measure changes in milk production. A 'non-advised' group of farmers were surveyed in order to allow for production changes that were not due to extension. Multiple regression analysis was also used to allow for other factors, besides advice, that might have been associated with changes in production, e.g. differing rates of change in production before advice, changes in farm size between the two surveys.

The study highlighted the difficulty with a longitudinal survey of measuring the payoff from advice because of other changes in the farming system which tend to obscure the effect of advice.

2.2.2 Changes in Efficiency

A different type of methodology for the evaluation of an extension programme was proposed and tested empirically by Alves and Schuh (1968). The method was based on a comparison of firms on their level of technical efficiency (the ability to choose the correct production function) and on the level of price efficiency (the ability to maximise profit within a given environment and production function).

Alves and Schuh pointed out that the effectiveness of an extension programme which set out to increase price efficiency may be under rated if it was only evaluated on the basis of changes in technical efficiency.

The authors applied the model to a sample of farms from two Brazilian counties, one of which had received an extension service for the previous 10 years. The data was collected in direct farm interviews and used to estimate the basic production function (assumed to be Cobb-Douglas). The farms in the two counties were ranked on their levels of price, technical and overall efficiency.

Testing was based on the hypothesis that farms from the county that received the extension service would have a higher level of technical efficiency but a lower level of price efficiency.

It was expected that the adoption of new technology would have changed both the underlying production function and the resource proportions, but would not have improved price efficiency, since the extension service gave little attention to the economic dimension in its technical assistance programme.

They concluded that they had demonstrated the feasibility of this ex post evaluation method and suggested that it lent itself to longitudinal analysis. However, they did admit to some doubt about the similarity of the counties in every respect, except for the 'treatment effect' of extension. This problem of finding a group of farms which can act as the control group is likely to be more acute in a smaller country like New Zealand with a more highly developed agriculture.

Alves and Schuh recommended that the extension service pay greater attention to the economic dimension of an extension programme where there was limited capacity for biological and technical research, such as in Brazil, with the corresponding lack of new technical knowledge to distribute to the farmer.

2.2.3 Analysis of Commodity Potential

A method which has been specifically developed to assist the United Kingdom advisory service, ADAS with the problem of the allocation of its resources is reported on in an OECD working document 'Evaluation of Advisory Work' (OECD, ibid). The method is called 'Commodity Analysis' and it is an attempt to measure for each commodity e.g. milk, the opportunities for additional income, using available technology.

The following formula is applied to the various productions of an agricultural region:

$$\Delta P = (P_j \times N_j) \times E$$

where ΔP is the potential increase in net agricultural income for a production P in the light of available techniques (the ADAS experts call it the existing 'financial loss');

where P_j is the additional net income attributable to applying to production P a hitherto unused technique (e.g. adopting more productive wheat variety);

where N_j is the number of production units to which the technique j can be applied (e.g. number of hectares on which the variety in question has not yet been sown);

where E is a co-efficient less than 1, expressing that part of the theoretically possible progress which will be effectively achieved in view of widely varying difficulties including both farmer resistance and the advisory service's inadequate resources or technical skill.

A comparison of the various values calculated for P is used to help the advisory service in choosing its objectives although, according to the OECD report, the final decision also depends on the number of farmers who are affected by the problem.

This method, as well as being an attempt to predict the expected value of alternative advisory objectives, also takes account, through the co-efficient E, of the extension agency's prior subjective estimate of the producer's response to each of these objectives. This attempt to incorporate the subjective judgements of the decision maker resembles the decision-theoretic approach, in which the decision maker's personal probabilities about the uncertain events are used to help solve the problem. Both these points, a preposterior analysis and the use of the decision maker's prior judgements make this method of evaluation similar to the one proposed in this thesis.

2.3 THE NEED FOR PREPOSTERIOR ANALYSIS

The extension agency may decide that it requires additional information about the effects of the alternative extension messages to assist it with its resource allocation problem. But the agency must make a decision about the value of an extension message without having completely determined the consequences of that message. Even if it was technically possible to determine the consequences by, for example, surveying all the farmers to whom the message applied, it would obviously be too costly.

Therefore, the agency must be satisfied with the 'partial' information which it can obtain from a 'preposterior' analysis.

But most of the methods for measuring the benefits of extension, which have been reviewed above, have been developed for a 'posterior analysis' or the <u>ex post</u> evaluation of additional information which has been provided to farmers.

The exception is the UK method of commodity analysis which requires the extension agent to make an estimate of the benefit of an extension message, i.e. there is an attempt to appraise the value of an extension message before it is incorporated into an extension programme.

2.4 UNCERTAINTY AND THE EVALUATION OF EXTENSION

None of the methods for assessing the value of advice, which have so far been outlined, take explicit account of the uncertain consequences which may be associated with an extension message.

2.4.1 Uncertainty and Technical Change

The uncertainty associated with a new technique is a factor which plays a major role in determining the speed of diffusion (Nelson et al, 1967). They suggested three factors wiich were related to uncertainty and its resolution in the adoption of an innovation.

1. Extent to which the innovation may be tried out on a small scale.

2. Extent to which potential users include a group with education and training which permits the information to be decoded and understood.

3. Strength of the information dissemination system.

Likewise, Lever (ibid) pointed to the uncertainty of the benefits and costs of a change as being important in the rate of adoption of technical change.

Campbell (1962) in a discussion of the implications of farm decision making for agricultural extension argued that advice should take more account of risk. Likewise, Anderson (1974) said that extension in risky agriculture will probably be more effective if due recognition is given to the impact of risk.

Many of the factors which have been suggested as affecting the adoption of technical change are virtually another aspect of the uncertainty associated with the change. Lever (ibid) suggested that there are three main factor groups, the technical system, community norms and personal characteristics which influence adoption of a change. Each of these has a dimension of uncertainty associated with it. For example, Lever suggests the closeness of an innovation to techniques at present in use, as being important, because it is more easily understood, can be more confidently evaluated and it is more likely to be readily integrated with the existing farming system. These factors of compatability and complexity are also listed by Rogers and Burdge (1972) as important characteristics which affect adoption. The importance of these factors seems to be in their effect on the uncertainty of the consequences of the change.

The extent to which a change can be tested on a small scale is another characteristic which is often noted as being important in the adoption process. The significance of this is probably through the change in uncertainty which can result from the additional information from a small scale trial.

2.4.2 THE CLIENT

As well as the uncertainty associated with the change having an influence on its acceptance there is also the effect of the client's attitude to uncertainty. If farmers are averse to the uncertainty which they face when making decisions this will influence their choice when, for example, two alternatives provide the same increase in average net income but one of them has a greater chance of an unfavourable consequence.

Lever suggests that it is the ability of a farmer to bear the risk of change which characterises the early innovator. Their successful adoption of a change will help to reduce the uncertainty for other members of the community.

2.4.3 The Extension Agency

The extension agency may also be averse to the uncertainty of the consequences associated with some of its extension messages because of the undesirable carry-over effects which may occur if clients obtain a bad outcome. Farmers may discount the value of further advice from an extension agent if they associated a bad outcome with advice previously received from the agency. An example, that might be applicable under N.Z. conditions, arises from the comment made by farmers that the advice they received during the 1960's to increase stock numbers has resulted in extra work but not in extra net income. It is possible that this apparently bad outcome has influenced farmer's perceptions of the advice which they have been offered in subsequent years. (4)

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(4) It should of course be realised that although the information that the extension agency provides to its clients will help to ensure that the best decision is made, it is not possible to ensure that the best <u>outcome</u> occurs. The outcome or the consequence of a decision depends on the uncertain event which happens to occur and which is beyond the control of the decision maker or his adviser.

The best that the extension agency can do is to take into account the farmer's beliefs about the uncertainty associated with a course of action and their preferences for the uncertain consequences in an attempt to define the real value to farmers of an extension message.

2.5 SUMMARY

The way in which an extension message may affect a farmer's decisions is discussed and some of the reported methods for assessing the value of an extension message are reviewed. There is also some discussion of the influence of uncertainty on the value of an extension message.

Most of the methods for evaluating an extension programme have been based on an ex post analysis of the benefits. The exception was the commodity potential analysis which also used the extension agency's subjective assessment of the benefit of extension messages to make a preposterior estimate of the likely value of the alternatives.

However, the author considered that there was a need for a method which would assist the agency to make a choice amongst the alternative extension strategies.

3. THE THEORETICAL BASIS OF A METHOD FOR THE PREPOSTERIOR EVALUATION OF AN AGRICULTURAL EXTENSION PROGRAMME

3.0 INTRODUCTION

In the previous chapter it was suggested that the information which the extension agency passes on to farmers, the extension message, assists farmers to make decisions. Within the framework of Bernoullian decision theory this information can have two main effects which need to be considered in any attempt to evaluate an extension message. The information can help to revise a farmer's payoff matrix or it can help to assess the probabilities of the uncertain events.

It has also been noted that the problem for the extension agency is to allocate its resources to the various combinations of extension messages and clients so as to maximise the present value of the change in aggregate farm incomes due to extension.

The purpose of this chapter is to describe the way in which an extension agency can make a preposterior estimate of the value of an extension message.

3.1 THE PRIOR VALUATION OF AN EXTENSION MESSAGE

The extension agency will have prior knowledge of the information alternatives and we assume it will have prior knowledge of the value of the various information messages.

Let I_{ik} equal the i-th extension intensity for the message I_k, where intesnity will be some combination of extension time and other resources.

Let $u'(I_{ik})$ be the agency's prior estimate of the value of the i-th extension intensity for the message I_k.

The prior valuation of I_{ik} by the agency will be, in many cases, largely subjective and is the prior assessment of the present value of the long-run change in aggregate farm incomes that is expected to result from extending the message I_k. It will, for example, be close to zero if the message relates to a problem that is believed to be of little concern to farmers.

The way in whcih the value of an extension message might vary with intensity has already been discussed in Section 2.2 of the previous chapter.

The agency can allocate its resources to the extension messages on the basis of its prior valuations.

This approach differs from the present practice of the Advisory Services Division of MAF which apparently allocates its largest resource, its extension workers, so that all farmers are offered a similar level of service. This system is described by Rodgers et al (1975). Under this system advisory officers are appointed to districts which, as far as is practical, contain a similar number of farmers.

On the basis of this approach, Rodgers et al (ibid) have applied a particular method, facility location analysis, and obtained several alternative patterns of location of farm advisory officers of MAF which were lower cost solutions than the Ministry's plan based on its prior knowledge.

However, each advisory officer is expected to decide for his alloted district and its farmers, how he should allocate the Division's resources in order to best achieve its advisory goals.

There is virtually no information about how MAF advisers do, in practice, make their planning decisions. They are provided with a booklet prepared by MAF, called Guidelines to Planning Advisory Work (1972), which recommends a format for writing down the adviser's choice of a work plan. This booklet suggests the use of 'a subjective assessment' to help choose the extension objective or message which is the basis of a work plan.

However, it is almost certainly correct to assume that advisory officers of the MAF do have information about the alternative extension messages which are applicable to the farmers in their district and about the value of these messages. The extent of this information will obviously vary with such factors as the length of time the adviser has spent in a district.

3.2 THE DECISION TO OBTAIN ADDITIONAL INFORMATION ABOUT THE ALTERNATIVES

The extension agency might not wish to decide immediately about the allocation of its resources. It has the option of seeking sample information from a survey of actual and/or potential clients, and to use this additional information to revise its prior estimate, $u'(I_{ik})$, of the value of an extension message.

If we let $u''(I_{ik})$ equal the revised or posterior estimate, the option to obtain the sample information can be expressed as in figure 3.1

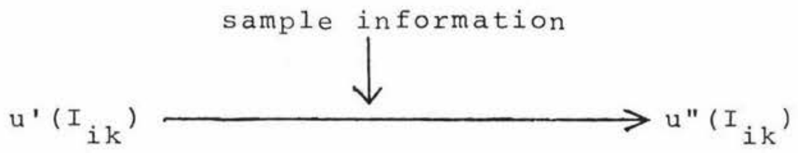

Figure 3.1 Decision to Obtain Sample Information

An important decision now relates to the size of the sample. The time spent on this sampling probably has a high opportunity cost since it could be spent providing extension information.

However, it seems to be accepted, in practice, that MAF advisers spend much of the first few years in a district becoming familiar with its problems. So that the cost of obtaining sample information about the value of alternative extension messages may not be much greater than that already incurred when an adviser is allotted a district.

For any given sample size, say n farmers, the agency could, for each farmer:

1. List their perceived problems,
2. List their perceived alternatives for the solution of each problem,
3. Determine the mean and variance of the farm income associated with each alternative.

The agency would then extend information I_{ik}, and then repeat steps 2 and 3.

This would allow the mean and variance of the <u>change</u> in farm income due to I_{ik} to be estimated, and therefore the aggregate changes could also be estimated.

The sample information, so obtained, is then used to revise $u'(I_{ik})$ to $u''(I_{ik})$ and the agency now allocates its resources given the posterior value or else it decides to take a further sample.

If we now consider each farmer in the sample, the situation might be similar to the following:

For farmer i -

Net Farm Income	=	f (Revenue, Costs)
Revenue	=	g (Prices, Yields)
Yield	=	$h\ (X_i,\ Z_j \mid T)$
where h	=	input/output relationship
X_i	=	controllable inputs
Z_j	=	non-controllable inputs
T	=	technology

Therefore, net farm income is a random variable with some mean and variance.

The extension agency gives advice on:

- the nature of the input/output relationship
- new alternatives not considered by the farmer
- technology
- and, perhaps less commonly, prices

In order to account for the different types of advice it is necessary to specify a stochastic budgeting decision model with the farmer's prior probability estimates. The sample farmers are then given the advice and the model of their problem is modified. This might involve adding new acts and/or revising the farmer's prior probabilities using Bayes' theorem.

Bayes' theorem is used with the <u>sample of farmers</u> to revise <u>their</u> probabilities in order to help estimate the value of the advice to the farmer.

Bayes' theorem is also used by the <u>agency</u> to help it revise <u>its</u> prior estimate of the value of an extension message.

3.3 THE VALUE OF AN EXTENSION MESSAGE TO A FARMER

In the case of an extension message which assists the farmer through the revision of his pay off matrix, the value of this advice could be obtained by implementing the steps outlined in the previous section.

This section provides an outline of the way in which to measure the value of an extension message which provides information about the occurrence of the uncertain events in a decision problem.

The farmer, given some information x_k, about the occurrence of the i-th (i = 1, 2 ...., m) uncertain event, θ_i, should change the prior probabilities, $p(\theta_i)$, to revised or posterior probabilities, $p(\theta_i|x_k)$. The extent of the revision is given by Bayes' formula.

$$p(\theta_i|x_k) \quad = \quad p(x_k|\theta_i) \quad p(\theta_i) \qquad \sum_{i=1}^{m} p(\theta_i) \quad p(x_k|\theta_i) \qquad (3.1)$$

The farmer or the agency uses the posterior probabilities in the evaluation of the alternatives to obtain the optimal action with the additional information.

Before the information is obtained, the farmer's best action is the one with the highest expected pay off $u(A_j^*)$. This is defined by the equation:

$$u(A_j^*) = \max_j \sum_{i=1}^{m} c_{ij} \quad p(\theta_i) \tag{3.2}$$

Where c_{ij} is the consequence of the i-th uncertain event and the j-th course of action. It is assumed that the c_{ij} are measured in terms of the mean and variance of net farm income, i.e. that the farmer's utility is a function of the mean and variance of net farm income.

Given the posterior probabilities, the action with the maximum expected pay off for a particular forecast x_k, is defined as $u(A_j^{**})$ and is given by equation (3.3)

$$u(A_j^{**}) = \max_j \sum_{i=1}^{m} c_{ij} \quad p(\theta_i | x_k) \tag{3.3}$$

To carry out a preposterior analysis of the information it is necessary to evaluate the various possible forms that it might take. Suppose there are m possible uncertain events and the additional information x, consists of a prediction x_k of the occurrence of the i-th (i = 1, 2, ..., m) uncertain event. There is thus a set $\{x_k\}$ of m possible predictions or forecasts.

The essence of the Bayesian computation procedure is to evaluate each action under the posterior probabilities associated with each forecast as in the equation (3.4),

$$u(A_j | x_k) = \sum_{i=1}^{m} c_{ij} \quad p(\theta_i | x_k) \tag{3.4}$$

The action which gives the highest pay off for a particular forecast, as in equation (3.3), is then the strategy component for that forecast.

If we denote by A^{**}_{jk} ($j = 1, 2, \ldots, n$; $k = 1,2, \ldots, m$) the optimal action for the k-th forecast x_k, the optimal strategy may be specified by the m-element vector.

$$\{A^{**}_{jk}\} = (A^{**}_{j1}, A^{**}_{j2}, \ldots\ldots, A^{**}_{jk}, \ldots, A^{**}_{jm}) \qquad (3.5)$$

The probability that each of these actions will be followed is the probability that its associated prediction x_k, will occur which is given by equation (3.6),

$$p(x_k) = \sum_{i=1}^{m} p(\theta_i) \quad p(x_k|\theta_i) \qquad (3.6)$$

The pay off of the optimal strategy can therefore be calculated from equation (3.7) as the weighted average:

$$u(\{A^{**}_{jk}\}) = \sum_{k=1}^{m} u\ (A^{**}_{jk}) \quad p(x_k) \qquad (3.7)$$

Without the additional information from the set of predictions the optimal action based on the prior probabilities $p(\theta_i)$, is that specified by equation (3.2). The expected value of the information is therefore the difference between the pay off expected with the information, given by equation (3.7), and the expected pay off if the prior optimal act is used, i.e. A^*_j. Therefore the pay off to the farmer from the additional information is the difference in pay offs between the prior optimal action and the posterior optimal strategy, i.e:

$$u(\{x_k\}) = u(\{A^{**}_{jk}\}) - u(A^*_j) \qquad (3.8)$$

When the consequences of the actions, in utility terms, are not a linear function of net farm income, as for example, when utility is a function of the mean and variance of net income, the monetary equivalent of u(x_k) can be found. It is necessary to find the monetary value of that term which, when subtracted from each element of the pay off matrix, equates the expected value of the posterior optimal action to the expected value of the prior optimal action.

From the farmer's point of view, the greater the value of the term $u(x_k)$, the greater the expected value of the advice or additional information provided by the extension agency. From the agency's point of view, the data which it obtains from the sample of farmers about the value of the extension message, I_{ik}, will be used to revise its prior estimate, $u'(I_{ik})$ to a posterior estimate $u''(I_{ik})$.

3.4 THE POTENTIAL FOR INFORMATION IN A DECISION PROBLEM

The extension agency can obtain a preposterior estimate of the upper limit of the value of information about the uncertainty in a farmer's decision problem. This data, if it was available for several decision problems, should assist the agency to choose the problem that has the greatest potential for an extension programme.

The expected value of perfect information for the k-th problem x_k^*, may be calculated as follows. Perfect information implies a posterior probability of unity for some particular occurrence of the uncertain event and of zero for all others.

Also, with perfect information, the optimal action may always be chosen. This action will be the one which yields the highest pay off given the known occurrence of the uncertain event. The expected pay off of the strategy based upon the perfect information $u(A^{**}_j)$ is given by equation (3.9),

$$u(A^{**}_j) = \sum_{i=1}^{m} \max_j c_{ij} \quad p(\theta_i) \qquad (3.9)$$

Before any advice from the agency is available to the farmer, the expected pay off of the best action is given by equation (3.2).

Therefore, the expected value of perfect information, $u(x_k^*)$ is the difference between the expected pay off of the strategy with perfect information, equation (3.9), and the expected pay off of the prior optimal action, that is

$$u(x_k^*) = \sum_{i=1}^{m} \max_j \; c_{ij} \; p(\theta_i) - \max_j \sum_{i=1}^{m} c_{ij} \; p(\theta_i) \qquad (3.10)$$

3.5 THE REVISION OF A PRIOR ESTIMATE OF THE VALUE OF AN EXTENSION MESSAGE

The extension agency, having obtained an estimate of the value of the information x_k, to a sample of farmers, uses this information to revise its prior estimate of the value of the extension information $u'(I_{ik})$. The same revision process using Bayes' theorem, as has been outlined in the farmers' case, is applicable to the agency's use of the additional information.

However there is an alternative way of incorporating the information from the sample in the case where a normal prior distribution is an adequate representation of the random variable about which the agency is uncertain.

The true value of $u(I_{ik})$, the present value of the change in aggregate farm income from the extension message I_{ik}, is unknown. But providing the agency's information that is relevant to estimating it can be summarised in the form of a normal probability distribution, it is a straight forward matter to obtain a subjective estimate of the mean μ_o, and standard deviation σ_o, of the distribution. Intuitively a normal distribution seems a seasonable approximation to the distribution of $u(I_k)$; e.g. it should be equally possible for the random variable to take a value either side of the mean. (The assumption of a normal prior distribution is discussed further at the end of the chapter). It simply requires the agency to specify its best guess for the average increase in net farm income and the probability of estimating errors of a certain size (Jedamus and Frame, 1969).

If the agency decides to obtain additional information from a sample of farmers about the value of an extension message I_{ik}, it can do this by observing the change in net farm income for each farmer in the sample. But instead of the agency carrying out the revision process for each farmer as outlined in the previous section; the agency just obtains data on the change in farm income attributable to I_{ik}.

It is assumed that the farmer, on being given the information I_{ik}, revises his prior probabilities according to Bayes' formula and this change is reflected in changes in the budgeted pay offs of the alternative courses of action.

Let x_k denote the change in farm income from the extension message I_{ik} for a farmer in the sample. The distribution of the n observations of x_k is the information used by the agency to revise its prior estimate of the value of the extension message $u'(I_{ik})$.

The sampling distribution of $\bar{x}_k$ values will be normal for small samples of farmers providing the parent distribution of $u(I_{ik})$ is normal. The mean of the sampling distribution of the mean is equal to the mean of the population and its standard deviation will be $\sigma(\bar{x}_k)$, the standard error of the mean.

With normal prior and sampling distributions, the revised estimating distribution will also be normal and its mean and variance can be easily obtained (Jedamus and Frame, ibid).

The mean of the revised distribution , μ_r is given by the equation:

$$\mu_r = \frac{IC_o \ \mu_o + IC_{\bar{x}} \ \bar{x}_k}{IC_o + IC_{\bar{x}}} \qquad (3.9)$$

where,

IC_o = information content of the prior distribution
= the reciprocal of the variance of the prior distribution, $1/\sigma_o^2$

$IC_{\bar{x}}$ = information content of a sample
= the reciprocal of the variance of the sampling distribution, $1/\sigma^2(\bar{x}_k)$

But the standard error of the mean $s(\bar{x}_k)$ is given by the formula (Jedamus and Frame, ibid):

$$s(\bar{x}_k) \quad = \quad s(x_k)/\ n$$

where $s(x_k)$ is the estimate of the population standard deviation based on sample data, therefore,

$$IC_{\bar{x}} = 1/(s(\bar{x}_k)/n)^2$$
$$= n/s^2(x_k)$$

Thus the revised mean is an ordinary weighted average of the prior mean and sample mean, where the weights used are the information contents of the prior distribution and sample, respectively.

The information content of the revised distribution is the sum of information provided by the prior and sampling distributions

$$IC_r = IC_o + IC_{\bar{x}} \qquad (3.10)$$

The variance of the revised distribution can be obtained from the above formula as:

$$\sigma_r^2 = \frac{\sigma_o^2 \quad s^2(\bar{x}_k)}{\sigma_o^2 + s^2(\bar{x}_k)} \qquad (3.11)$$

The mean μ_r, and variance σ_r^2, of the revised distribution provide the posterior estimate of the change in farm income due to the extension message, i.e. $u''(I_{ik})$ is a function of μ_r and σ_r^2. This is the information which the agency should use to assist in the allocation of its resources.

Since the revised distribution is also normal, further information from a sample of farmers can be incorporated as it becomes available, by repeating the revision process, treating the revised distribution as if it were a prior distribution.

3.6 DEPARTURES FROM NORMALITY

In the case of a non-normal prior distribution, unless the agencies' prior estimates of μ_o and σ_o are very definite (small μ_o and high IC_o) and quite non-normal, the formulas shown above for the normal case can be used without a serious loss of accuracy. Usually, the information content of the prior distribution is small relative to that of the sampling distribution, in which case the shape of the prior distribution will have little effect on either the shape of the revised distribution or the numerical values calculated as its parameters.

If the sampling distribution is non-normal because the parent population from which the samples are shown departs seriously from normality this can be rectified by increasing the size of the sample.

3.7 THE METHOD AND THE RULES OF STOCHASTIC DOMINANCE

Although it has been assumed that we know the way in which the agency and the farmer's utility varies with changes in the mean and variance of net farm income, there is another way of comparing alternative courses of action with uncertain outcomes that does not require the decision-maker's utility function to be defined.

Instead, the revised distributions for two alternative extension messages, say $u''(I_{ik})$ and $u''(I_{il})$ are compared using the rules of stochastic dominance. The theoretical basis of the rules and examples of its application in the interpretation of agricultural production research are given by Anderson (1974). Some assumptions are made about the decision-maker's preferences for uncertain outcomes and the extent of these depends on the difficulty of defining the dominant alternative.

The use of the rules should make it possible to develop extension messages about alternatives which were suitable for farmers according to their aversion, preference or indifference to risk. Providing the agency could assess informally a farmer's attitude to risk it would be possible to give the best advice, from a risk-efficient point of view, without measuring the individual's utility function.

3.8 SUMMARY

A method is outlined, based on Bernoullian decision theory, by which additional information about the expected value of alternative extension messages is obtained from a sample of farmers. This information is incorporated with the agency's prior subjective estimates to obtain a revised estimate of the value of the alternative messages which is used by the agency in its allocation of resources.

4. AN APPLICATION OF THE EVALUATION METHOD IN THE CONTEXT OF A FARMER'S DECISION PROBLEM

4.0 INTRODUCTION

The extension agency has the problem of choosing the extension message, or the combination of alternative extension messages, that will return the most benefit to the resources which it can allocate to achieving its purpose. It would assist the agency with this choice if it could obtain data about the value to farmers of the alternative extension messages.

In the previous chapter it was hypothesised that Bernoullian decision theory is applicable to the extension agency's resource allocation problem.

Also, as outlined in the previous chapter, part of the problem of obtaining data about the value to farmers of an extension message, is to obtain a measure of the farmer's expected outcome if he does not receive a particular extension message. In order to assess the expected value of an extension message it is necessary to take account of the situation which would have existed if there had been no input of extension resources.

This chapter reports on an attempt to define for a farmer the expected outcome of a decision problem by using the farmer's information about the problem, the alternative courses of action and by obtaining an estimate of the outcomes of these actions in terms that were relevant to the goals expressed by the farmer.

It was expected that this information would provide a measure of the farmer's expected utility, as a result of taking one of the actions without having received advice, or a measure of the 'without-advice' situation.

It was also expected that it would be possible to evaluate the potential for additional information to assist the farmer with his decision problem. This data about the potential for additional information should assist the extension agency to estimate the value of the alternative extension messages.

As a result of this research the author expected that it would be possible to draw some conclusions about the applicability of Bernoullian decision theory to the extension agency's problem of defining the without-advice situation, and the difficulties of applying the theory to this aspect of the problem.

4.1 THE RESEARCH DESIGN

The intended research procedure was to obtain sufficient information from a small number of farms to enable the farmer's decision problems and alternative courses of action to be defined. It was also intended to budget-out the farmers' estimates for the consequences of the various actions and relate these to the farmers' preferences using an estimate of each farmers' utility function.

The author considered that a detailed investigation of a few farms would be the best method of assessing the applicability of the theory to the problem. As well as finding out whether the decision-making model was able to adequately represent the farmer's decision problem it was thought that the study would expose parts of the farming system where there was potential for additional information to assist the farmer. These parts would provide a basis for the extension agency to formulate an extension message.

Although four farmers were interviewed over the course of three or more visits to each farm, the following will report in detail on only one farmer. This is because it was found necessary to make a more detailed investigation of the farming system than was at first thought necessary, and with limited time for the research it was only possible to carry this out on one farm. Most of the problems with the research method are apparent from the discussion of the one farm.

4.2 THE SURVEYED FARM

The farm that was used in the research project is a factory supply dairy farm in southern Manawatu, 64 km south of Palmerston North. The farmer had provided the author with information for an earlier research project. His willingness to provide information, as well as being a dairy farmer and handy to Palmerston North, were the main criteria for selection of the particular farmer.

The farm is 29 ha, flat and low lying. The soil type is Kairanga clay loam which is derived from alluvium and strongly gleyed. Adequate winter drainage is supplied by open drains which discharge into a tributary of the Manawatu River which borders the farm. The farmer thought the extensive drainage system tended to reduce the ground water table in summer to such a low level as to cause over-drainage.

The moisture holding capacity of the soil and evapotranspiration rate were estimated by Scotter (pers. comm.) to be similar to the Dannevirke silt loam which was estimated by Gibb (1973) to have an average moisture reserve (1) of 24 days.

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(1) The average moisture reserve as defined by Gibb is the period in days which would be required to deplete a soil at field capacity of all available moisture - a droughtiness rating.

At the time of the interviews the farm was running 65 milking cows, 14 yearling heifers, 17 heifer calves, 5 steer calves and 1 bull, or the equivalent of about three milking cows per hectare.

The number of milking cows had been about 65 to 70 for the previous seven seasons that the farmer had owned the farm except for 1972-73 and 1973-74 when he milked 77 and 83 cows respectively. During these two seasons the farmer had also leased about 10 ha which was used to winter the young stock and also provided some hay.

Production levels of milkfat had tended to be low and had ranged from 100 to 138 kg per cow for the previous seven seasons.

4.3 THE FARMER'S DECISION PROBLEM

The farmer was encouraged to express any problem which he considered was hindering progress towards his goal but it was found to be difficult to obtain any clear expression of a problem.

There had been a series of dry summers in recent years and all four farmers who were interviewed at this stage of the project were aware that the low summer rainfall had influenced their farm production.

Also, the farmer had changed his farming system in an attempt to reduce the affect of dry summers on production. He was growing a summer greenfeed crop for the third consecutive season.

All the farmers who were interviewed in the original survey had little idea, or found it difficult to express their farming problems. This finding supports the observation of

Hodgson (1971) and McKenzie (1976) that problem recognition is an extremely difficult and perplexing task.

Because of the difficulty of defining any other decision problems, which may have been partly due to the importance of the problem of uncertain summer rainfall, the author chose this problem as the one that should be studied.

4.4 THE FARMER'S ALTERNATIVES

Given the farmer's problem of how to run the farm in the face of an uncertain summer rainfall, the next step was to list the courses of action which the farmer perceived as alternative solutions to the problem.

Again, it was difficult to obtain from the farmer suggested changes to the present farming system which might be worth investigating. This was the case with all the farmers who were interviewed.

The two courses of action which the farmer seemed to consider as alternatives were either, to grow two paddocks of summer greenfeed crop, or not to grow any crop. The farmer had had experience with both alternatives, although for the past three years he had been growing a summer crop.

4.5 THE FARMER'S UTILITY FUNCTION

As with the decision problems and courses of action, there was an attempt to identify the dimensions of the farmer's utility function through discussion with him about his goals for the farm and by observing the terms he used when discussing the alternatives.

4.5.1 The Dimensions of Utility

The farmer estimated and described the payoff of the alternatives in kilograms of milkfat, dollars of income and expenditure and less often, in terms of changes in work load. If the farmer did use other less tangible, non-monetary elements in assessing the consequences he was not able to describe these dimensions of his utility function and it was difficult to identify them during the course of the intereviews.

Instead, the farmer seemed to regard the maintenance of the present level of net farm income as one of the most important elements of his farming objective. He was trying to repay a mortgage in order to avoid having to refinance, when it fell due within the next couple of years. To meet this commitment he needed to at least maintain the present level of income.

The farmer also indicated a preference for not increasing the number of milking cows. He had tried a substantial increase (about 20%) several years previously when he had leased some additional land and had experienced more severe pasture shortages, lower cow liveweights and per cow production. He preferred not to face the increased risk of the consequences of a higher stocking rate. His preference for the number of cows to be milked was taken into account when the alternative actions were being discussed with him.

4.5.2 The Measurement of the Farmer's Utility Function

The questioning procedure for deriving the farmer's utility as a function of money was based on the modified von Neumann-Morgenstern method. This approach was suggested by Officer and Halter (1968) as a practical one and it is outlined in detail in Makeham et al (1968).

The procedure requires the decision-maker to choose between two alternatives. One of these involves a gamble, with the outcomes being two sums of money, each with a 0.5 chance of winning. The other alternative has a certain sum of money as its outcome. By varying the so-called certain sum of money, it is possible to find the amount which makes the decision-maker indifferent between the two alternatives. Using this sum of money, called the 'certainty equivalent' and knowing the utility of one of the outcomes of the other alternatives, it is possible to derive the utility of the other outcome of the risky alternative (2).

This procedure, repeated for varying sums of money, gave a number of points on the farmer's utility function. A small chalk-board was a useful aid in the questioning procedure and the farmer quickly gained sufficient understanding of the method to be able to answer the questions.

The points obtained from the questioning procedure and the smoothed curve drawn through these points, is illustrated in Figure 4.1. The concave shape of the function and therefore diminishing marginal utility, indicates that the farmer is averse to risk, rather than being indifferent or having a preference for risk.

4.6 THE UNCERTAIN EVENTS

The sources of uncertainty which the farmer considered, when faced with the decision problem of how to farm through a dry summer, were identified in the course of discussion with the farmer. It was obvious from the definition of the problem that variations in summer rainfall were assumed to have a significant effect on the outcome of the decision alternatives.

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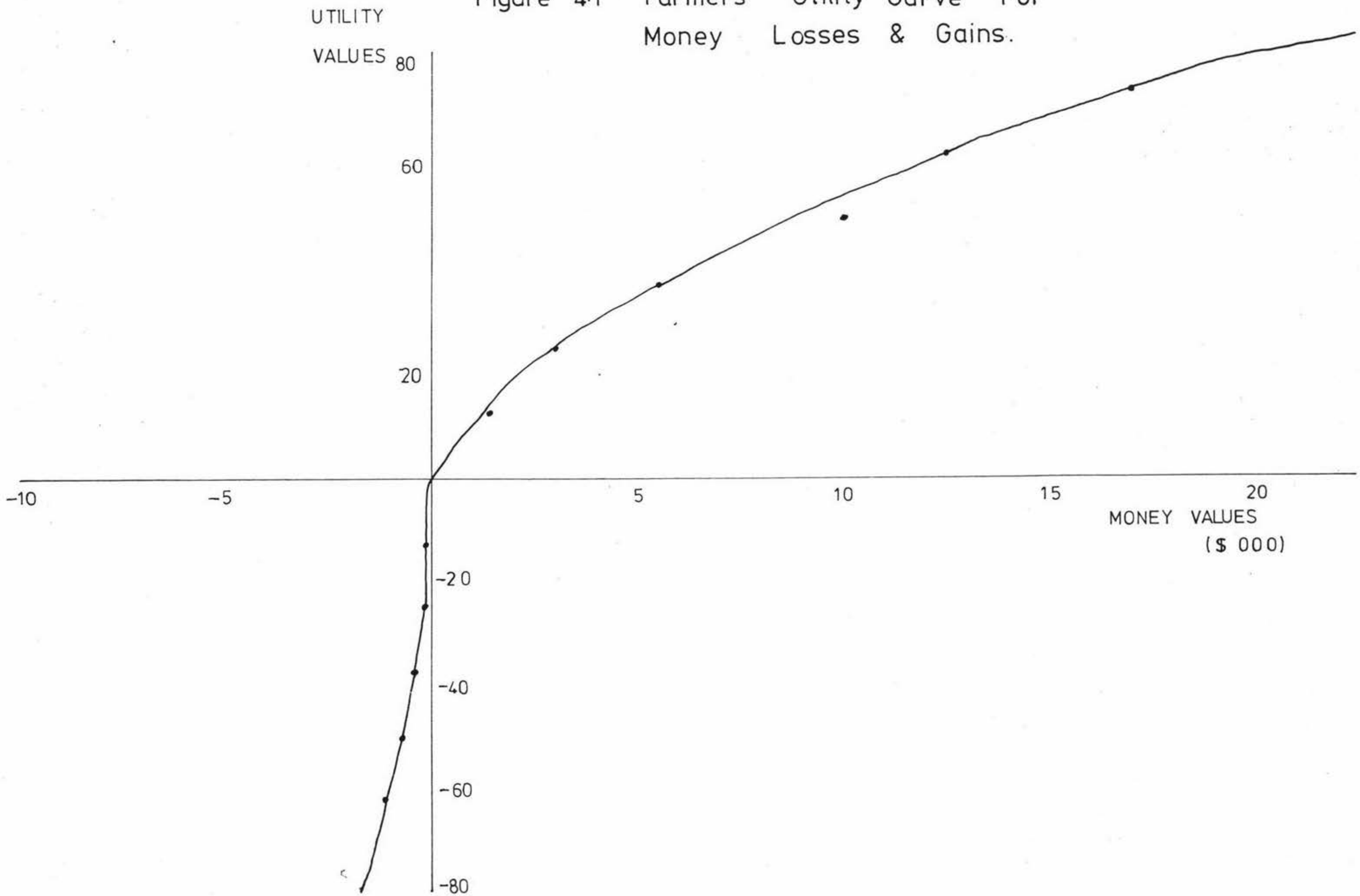
(2) One of the outcomes of the risky alternative in the first question is arbitrarily defined, e.g. a utility of 0 is assigned to $0 gain.

Figure 4.1 Farmers Utility Curve For Money Losses & Gains.



A brief discussion of the relationship between summer rainfall and production is given in Appendix I.

The price received by the farmer for milkfat was also thought to be an important source of uncertainty in the decision problem. At the time of the interviews the farmer agreed that he was uncertain about the milkfat payout for the next season (1976-77). Although the NZ dairy industry operates a guaranteed pricing scheme for milkfat, which sets the guaranteed price, at a national level, before the start of the season, farmers may still feel uncertain about the payout from the dairy company which they supply. For example, variations between years in the processing efficiency of the dairy factory may affect the season's payout.

4.6.1 The Assessment of the Uncertainty of Summer Rainfall

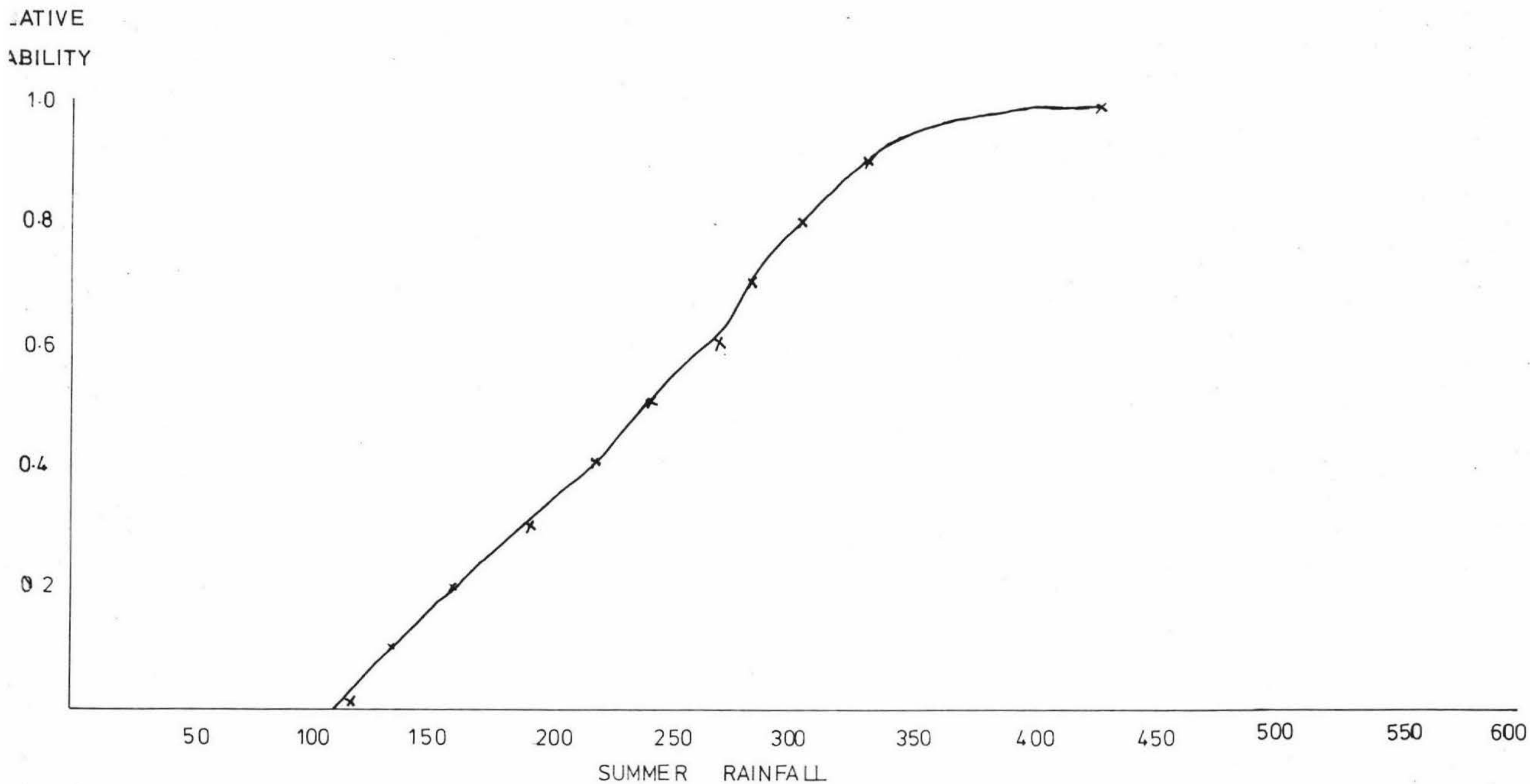
The assessment of the uncertainty of summer rainfall was based on frequencies of summer rainfall from NZ Meteorological Service records taken at a rainfall station situated about 5 km from the farm. The farmer agreed that there would be no significant difference in the monthly distribution of rainfall between the farm and the recording station.

The records, in the form of percentiles, (NZ Met. S., 1973 and pers. comm.) are the basis of the cumulative probability distribution for the uncertain event, summer rainfall (Figure 4.2). This procedure assumes that the historical relative frequencies for the uncertain event provide an adequate assessment of its probability distribution. The procedure is discussed in detail in Schlaifer (1959).

4.6.2 The Assessment of the Uncertainty of Milkfat Price

The farmer's assessment of the uncertainty associated with the event, the 1976/77 price for milkfat paid by the dairy company was obtained using amethod proposed by Raiffa (1968).

Figure 4.2 Cumulative Probability Distributions For Summer Rainfall (Based On NZ Meteorological Service Rainfall Percentiles)



It was thought that a historical frequency distribution of dairy company payouts was less likely to reflect the farmers' beliefs about the uncertainty, caused by factors occurring in the processing and marketing of milkfat.

The interview procedure for obtaining the farmer's subjective probability distribution of the uncertain event was first to define a price range giving the highest and lowest price that the farmer thought the payout could reach. The farmer was then asked to choose the prices, within the range, which divided it into equally likely fractiles. The questioning procedure was repeated so as to provide 7 points to the distribution. The resulting cumulative probability distribution, given by drawing a smoothed curve through the points, is shown in Figure 4.3.

As in the case of the rainfall probability distribution, the subjective probability distribution for milkfat price was divided into a number of discrete events. A probability for each event was obtained from the cumulative distribution (Fig. 4.3), and assigned to the price at the mid-point of each group. The method is outlined in detail in Schlaifer (1959).

4.6.3 Definition of Two Other Sources of Uncertainty

The first analysis of the farmer's decision problem was carried out incorporating the two sources of uncertainty, summer rainfall and milkfat price. However, it was suggested that there may be other sources of uncertainty which were not accounted for in the initial analysis. There were two reasons for the suggestion. There appeared from the initial analysis to be only limited scope for advice about rainfall and prices to assist the farmer with the problem. Secondly, advice about the two sources of uncertainty considered so far, is not the type of information which is usually provided by an extension worker about the problem.

For example, Murray (1973) gives information about the likely yields of summer crops and irrigation and associated milk production responses in a paper that addresses the problem of uncertain summer rainfall. Likewise, in a more recent issue of the Massey Dairy Farming Annual, the session on summer management contained information about the grazing management of pastures, (Matthews, 1975) together with more information on the topics covered by Murray.

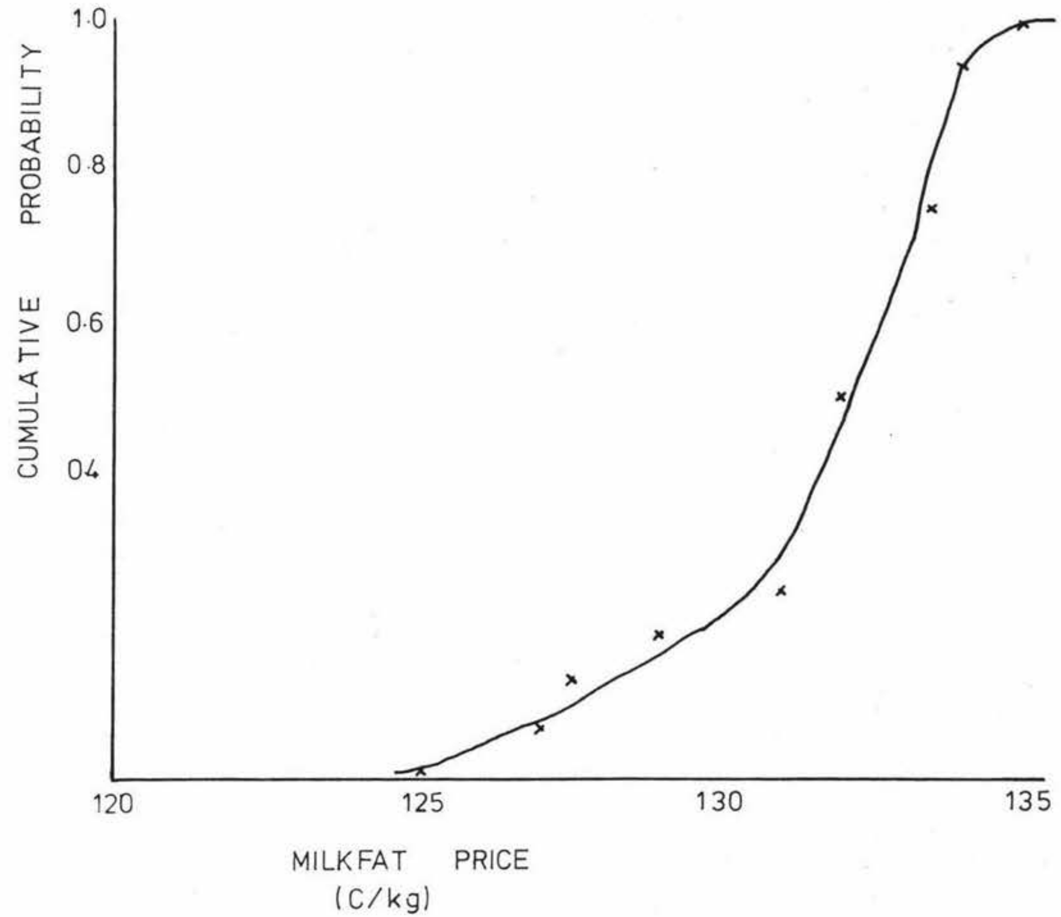
Therefore, it was decided to include pasture growth and milk fat output in the analysis of the problem because it was thought that these would be important sources of uncertainty in any attempt to estimate the outcome of alternative solutions to the problem.

4.6.3.1 Growth of Pasture

The model of the grazing system used in the initial analysis assumed that milkfat production was a function of the level of summer rainfall but this relationship ignored a number of other components of the system. Another model of the grazing system (Pollard , 1972) lists a number of other factors which interact with climatic factors to influence the rate of pasture growth. Pasture composition, soil type, soil nutrient availability, frequency and severity of grazing (grazing pressure) and treading effects are included in the list. Other climatic factors besides total summer rainfall, which are likely to influence pasture growth are its spread over the three motnhs, temperature and wind run.

Therefore, for any rainfall level, it is not possible for the farmer to do better than estimate a range of pasture growth rates. It may be that this uncertainty contains an element of 'ignorance' which Anderson (1972) describes as the analyst's uncertainty about the system, or his model of it, and which he suggests could usefully be distinguished from biological, climatological and price variation.

Figure 4.3 Farmer's Cumulative Judgemental Probabilty Distributions For The Uncertain Event '1976-77 Milkfat Price.'



However, in an attempt to introduce the uncertainty about pasture growth into the analysis this distinction was ignored and the uncertain event 'average daily pasture growth in summer' was defined and the farmer's beliefs about the uncertainty of this variable were assessed.

4.6.3.2. Output of Milkfat

Given a rate of pasture growth there are other factors in the grazing system which will lead to variations in the output of animal product and a list of these factors is described by Pollard (1972). For example, the farmer will probably be uncertain about the extent of the effect on pasture intake if he increases the grazing pressure. He may be uncertain about the quality of the pasture at different growth rates and he probably has little information on the liveweight of the herd or their conversion efficiency.

Therefore, in an attempt to assess the uncertainty associated with these components of the system, the level of milkfat production was assumed to be a stochastic variable for any given rate of pasture growth and the farmers beliefs about the uncertainty of this variable were assessed.

These two additional uncertain events, summer pasture growth rate and milkfat output, are both factors in the dairy cow grazing system about which advice is often provided. For example, one of the important sources of uncertainty in feed assessment and feed budgeting is the rate of pasture growth. Also, having estimated feed input in the budget there is the uncertainty about the level of milkfat ouptut as a result of a given level of feeding.

4.6.3.3 Measurement of the Uncertainty

Having chosen average daily pasture growth in summer as a variable that represented a significant source of uncertainty in the system, the next step was to measure the farmer's information about this variable. Although he did not think of pasture growth in terms of dry matter he was willing to express his beliefs about pasture growth in these terms. When questioned about the way he observed pasture growth, the farmer said that the amount of pasture left in the paddocks, after the herd had completed a rotation of the farm, was his indicator of pasture growth. It may have been possible, after more discussion with the farmer, to develop some measure of pasture growth which was more familiar to the farmer, but dry matter was chosen as the term of measurement because of the farmer's willingness to use this term and to keep the length of the interview within the limited amount of time.

Also, the little information that is available about pasture growth rates is measured in terms of dry matter/day.

As with the assessment of price uncertainty, Raiffa's (ibid) questioning procedure to obtain an estimate from the farmer of the uncertainty about pasture growth.

The farmer, in estimating the range of pasture growth over the summer, set the minimum at zero rate of growth but admitted to having little idea about a maximum level of growth in terms of kg dry matter per hectare. The author then provided the farmer with some information about maximum summer growth rates measured on the Massey No. 3 Dairy Farm (Holmes and Wheeler, undated) and the farmer chose 110 kg dry matter per hectare as a maximum daily summer growth rate.

The next step was to obtain the farmer's estimates of the relationship between variations in summer rainfall and variations in pasture growth. To do this a possible range of growth rates, given a low level of summer rainfall, was defined from discussion with the farmer. This was repeated for a medium and high level of summer rainfall. The upper and lower levels of pasture growth for the three levels of rainfall are presented in Table 4.1 as the 0.99 and 0.01 fractiles.

The overlap in growth rates for the three levels of rainfall, e.g. the upper level of pasture growth with a dry summer is about 34 kg dm per ha and the lower level in a medium rainfall summer is 22 kg dm per ha, adds emphasis to the uncertainty the farmer associated with the event.

Given these three ranges of summer pasture growth rates, the farmer was questioned to find the points that subdivided each into a number of equally-likely fractiles and these points are reported in Table 4.1. Based on these, the cumulative probability distributions that reflected the farmers' beliefs about the uncertainty in pasture growth under three levels of rainfall were determined and are shown as the smoothed curves in Figure 4.4.

The farmer's beliefs about the uncertainty of milkfat production for any level of summer rainfall and pasture growth were assessed using the same procedure as for the uncertain pasture growth.

The annual production of milkfat was defined as the random variable to which a probability distribution was to be assigned. This definition of the uncertain event had the advantage of being one that the farmer could easily relate with previous seasons' records of production.

The range of milkfat outputs was subdivided into five fractiles and a probability assessment for each fractile was obtained from the farmer for three rates of pasture growth, a low, medium and high level of pasture production. These assessments were made for both acts, growing a summer crop (a_1) and no crop (a_2). So the farmer provided probability estimates for a range of production levels given some level of pasture growth, with or without a crop.

Table 4.1 Judgemental Fractiles for the Uncertain Event 'Average Daily Pasture Growth Rate in Summer' For Three Levels of Summer Rainfall.

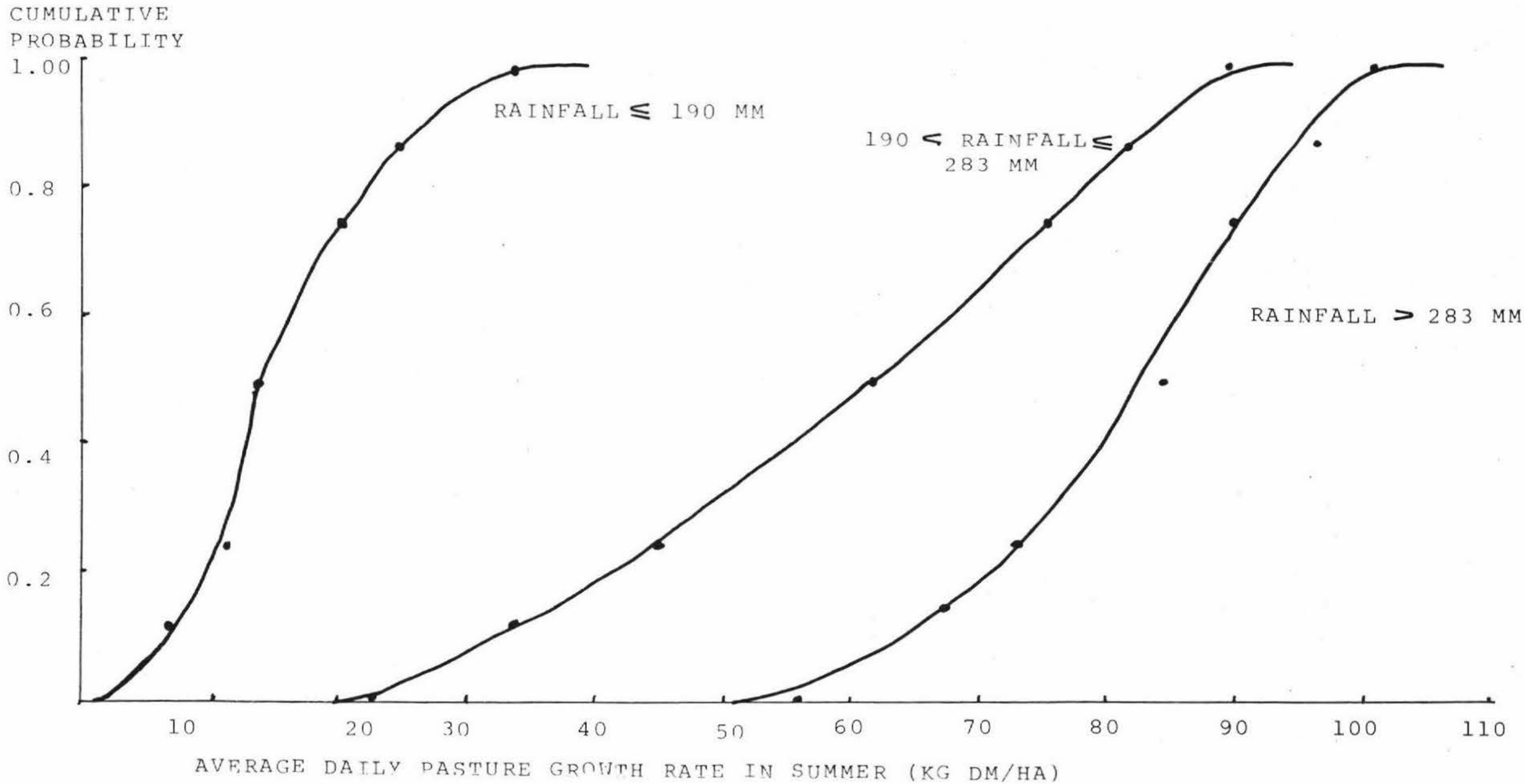
Fractile	Judgemental Fractiles for Pasture Growth Rate (kg DM/ha) At Three Levels of Summer Rainfall		
	Low (1)	Medium (2)	High (3)
.010	0	22.4	56.0
.125	6.7	33.6	67.3
.250	11.2	44.8	72.9
.500	13.5	61.6	84.1
.750	20.2	75.1	89.7
.875	24.7	81.8	96.4
.990	33.6	89.7	100.9

Note (1) Low - rainfall $\leq$ 190 mm

(2) Medium - 190 $<$ rainfall $\leq$ 283 mm

(3) High - rainfall $>$ 283 mm

FIG 4.4 THE CUMULATIVE PROBABILITY DISTRIBUTIONS FOR "AVERAGE DAILY PASTURE GROWTH RATE IN SUMMER" UNDER 3 RAINFALL LEVELS



A constant level of summer crop production was assumed. That is, the variations in yield as a result of variations in summer rainfall were not significant enough to effect the outcomes. The farmer considered this to be a reasonable assumption, because the crop had made the bulk of its growth prior to the period of uncertain rainfall.

A summary of the farmer's responses for assessing the distribution of the uncertain event, 'annual milkfat', are shown in Tables 4.2 and 4.3

The cumulative probability distributions for the uncertain events 'annual milkfat output with crop' and 'without crop' under three levels of pasture production that were derived from the farmer's responses are shown in Figure 4.5 and 4.6

4.7 METHOD OF ANALYSIS

The next step was to use the model of the grazing system described above, to provide a measure of the outcomes of the two courses of action given the levels of rainfall, pasture growth and milkfat output. The method used to obtain a measure of the outcomes from the model was to take a random sample of the combination of the uncertain events for each course of action. This is called the Monte Carlo method and is discussed in Schlaifer (1959).

To use this method the continuous probability distributions for the sources of uncertainty were reduced to ten discrete groups, each with the same probability of 0.1. This gave ten occurrences of each uncertain event, although in the case of summer rainfall these were aggregated to give three uncertain events which could be described as low, medium and high rainfall groups. The points, in terms of rainfall, which were assumed to define these three groups are shown in Table 4.4.

Table 4.2 Judgemental Fractiles for the Uncertain Event 'Annual Milkfat Output with Crop' under Three Levels of Pasture Production.

Fractile	Judgemental Fractiles given Three Levels of Pasture Growth		
	Low	Medium	High
		Annual Milkfat (kg)	
.010	6803	8163	9070
.125	7483	8617	9751
.250	7710	8844	9977
.500	8163	9070	10431
.750	8390	9206	10794
.875	8617	9524	10975
.990	9070	9977	11338

Table 4.3 Judgemental Fractiles for the Uncertain Event 'Annual Milkfat Output without Crop' under Three Levels of Pasture Production.

Fractile	Judgemental Fractiles Given Three Levels of Pasture Production		
	Low	Medium	High
		Annual Milkfat (kg)	
.010	6803	7483	9070
.125	7256	7710	9751
.250	7483	7800	9977
.500	7710	8163	10431
.750	8073	9070	10794
.875	8254	9206	10975
.990	8617	9524	11338

FIGURE 4.5 THE CUMULATIVE PROBABILITY DISTRIBUTIONS FOR THE "ANNUAL PRODUCTION OF MILKFAT WITH CROP" UNDER 3 LEVELS OF PASTURE PRODUCTION

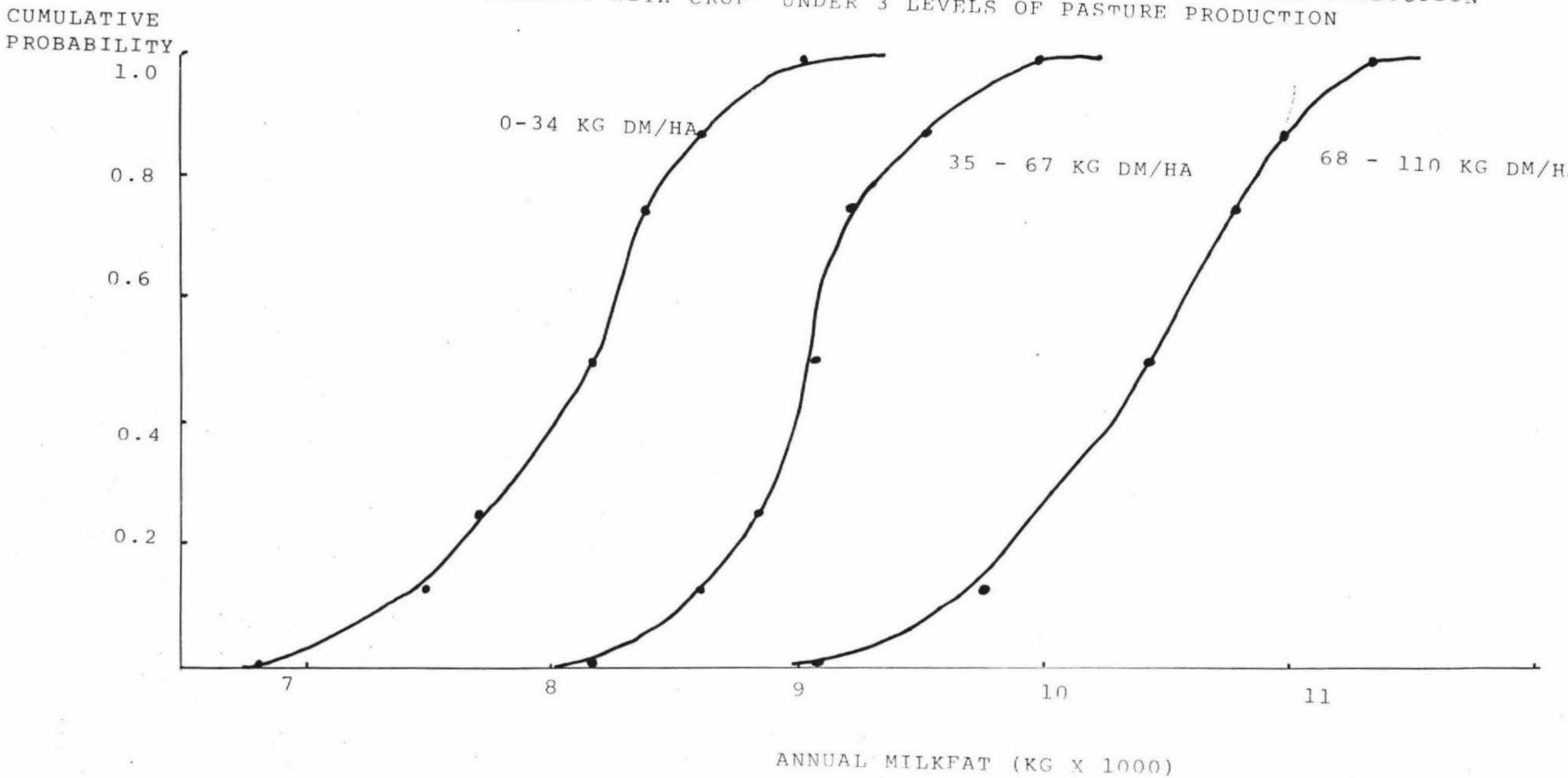
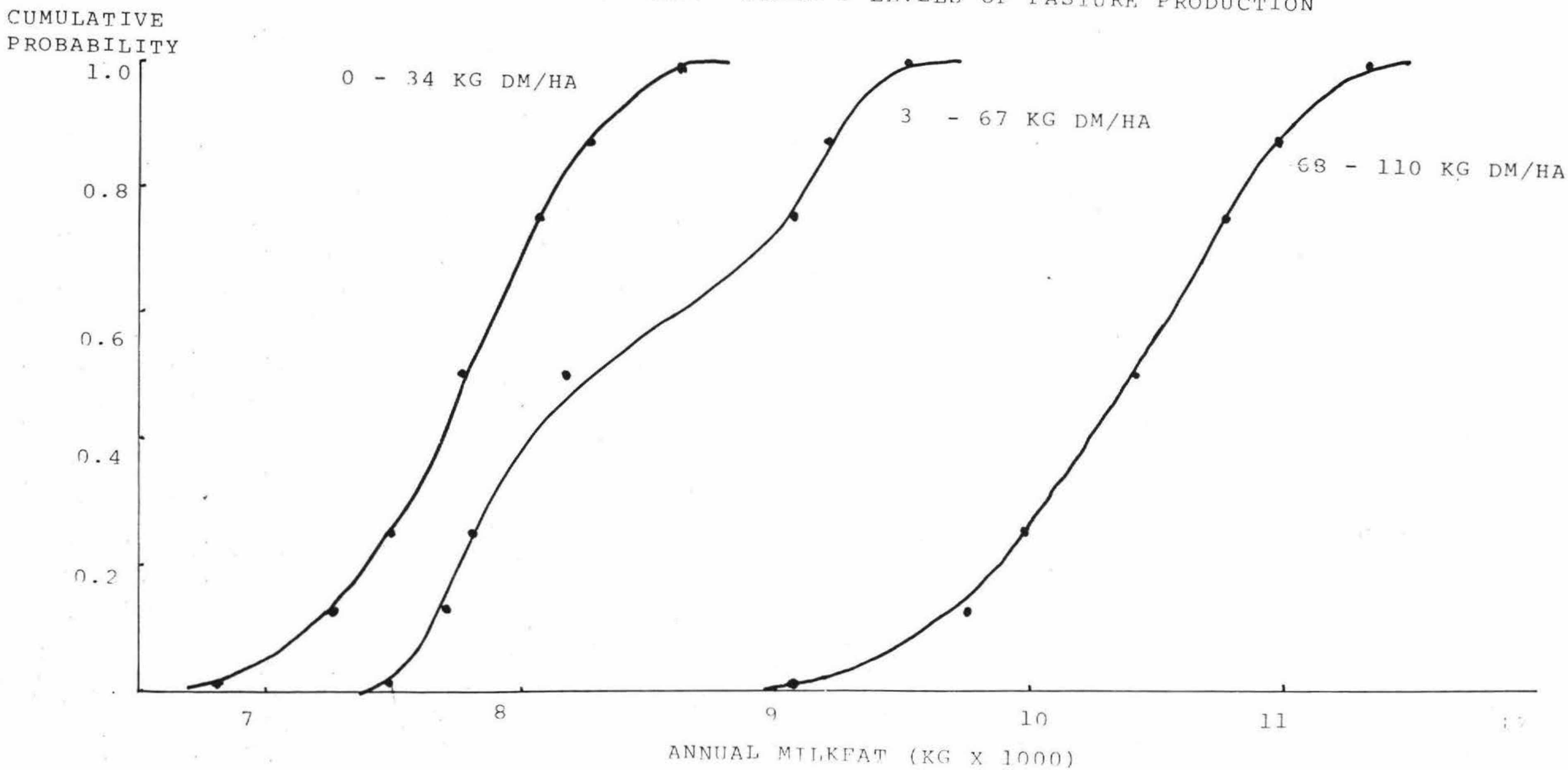


FIG 4.6 THE CUMULATIVE PROBABILITY DISTRIBUTIONS FOR THE "ANNUAL PRODUCTION OF MILKFAT WITHOUT CROP" UNDER 3 LEVELS OF PASTURE PRODUCTION



A table of random numbers was used to choose a sample of occurrences of each uncertain event, starting with summer rainfall. The points from each distribution from which the sampling was done are listed in Table 4.4. So, for example, in the first draw of random numbers a rainfall of 276 mm occurred, that is, a medium level of rainfall. The next draw was to pick a level of pasture growth that would be possible given a medium level of rainfall. This was 87 kg dry matter per hectare in the analysis. Given this rate of pasture growth, and a summer crop, another draw of random numbers was used to choose the level of milkfat production from the distribution of possible outputs defined in Table 4.4. This was 10 650 kg milkfat, which was one of the levels of production used in the payoff table, (Table 4.5). Finally, a random choice of milkfat price was obtained to define a point on the distribution of gross milkfat incomes (with a crop) which was used in the budget to define a level of net farm income. The results of 20 runs through this procedure are shown in the payoff table (Table 4.5).

There was no allowance in the budgets for variations in expenditure that might have occurred with variations in the uncertain events. As explained by Just (1974) in an investigation of the importance of risk in farmers decisions, 'many input costs are known with certainty at the time of decision making so that they have no effect on risk.' Accordingly, the cost of bought-in hay was constant at $650 (i.e. 1000 bales at 65 cents) for all occurrences of uncertain rainfall, pasture growth and milkfat output. (3)

The increased vehicle expenses and seed costs with growing a crop were assumed to be the only variations in expenditure

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(3) The cost of buying hay does vary with the level of summer rainfall but the farmer had a continuing arrangement to make hay on a nearby farm which helped to minimise variations in the cost of hay.

Table 4.4 Points from the Cumulative Probability Distributions of Rainfall, Pasture Growth, Milkfat Output and Price Used in the Monte Carlo Simulation

Cumulative Probability	Summer Rainfall (mm)	Pasture Growth Rate (kg DM/ha/day)			Milkfat Output With Crop (kg)			Milkfat Output Without Crop (kg)			Milkfat Price $/kg
		Summer Rainfall			Pasture Growth Rate			Pasture Growth Rate			
		<190 mm	190-283	>283	0-34	35-67	68-110	0-34	35-67	68-110	
0.05	110	4	27	59	7200	8350	9 355	7025	7550	9 355	1.262
0.15	150	8	37	67	7500	8650	9 755	7300	7700	9 755	1.292
0.25	178	11	45	73	7740	8850	10 000	7500	7800	10 000	1.309
0.35	207	12	52	78	7940	8950	10 155	7625	7950	10 155	1.315
0.45	234	13	58	81	8100	9005	10 350	7750	8150	10 350	1.319
0.55	256	15	64	84	8200	9055	10 500	7825	8450	10 500	1.322
0.65	276	17	70	87	8270	9125	10 650	7950	8800	10 650	1.326
0.75	297	20	75	90	8400	9205	10 755	8075	9050	10 755	1.330
0.85	321	24	81	94	8550	9450	10 950	8250	9200	10 950	1.335
0.95	365	30	87	99	8850	9800	11 200	8500	9400	11 200	1.342

Table 4.5 The Sample of Milkfat Outputs and Prices from the Monte Carlo Simulation and Resulting Net Farm Incomes and Utilities.

Milkfat Output (kg)		Milkfat	Net Income ($)		Utility	
a_1	a_2	Price ($/kg)	a_1	a_2	a_1	a_2
10650	10650	1.322	3318	3814	26	28
9755	9755	1.342	2591	3123	21	24
9125	8800	1.319	1745	1987	16	16
9355	9355	1.315	1972	2536	17	21
10350	10350	1.309	2923	3438	23	26
8850	7800	1.326	1502	957	13	8
8100	7750	1.315	634	844	6	8
8400	8075	1.319	984	1206	8	11
8400	8075	1.342	1138	1353	10	13
9205	9050	1.342	2003	2400	17	20
8950	7950	1.326	1616	1117	14	10
8100	7750	1.309	604	798	6	7
10000	10000	1.342	2847	3340	23	25
7740	7500	1.330	315	667	3	6
7200	7025	1.330	-403	74	-37	1
8100	7750	1.335	776	960	7	8
7940	7625	1.342	638	866	6	7
8850	8500	1.335	1582	1767	14	16
10000	10000	1.309	2590	3122	21	24
8350	7550	1.262	559	259	5	2

between the two courses of action and these were assumed to be known with certainty at the time of the analysis.

Likewise, on the income side of the budget the income from stock sales was assumed to be known with certainty when the budgets were drawn up (i.e. 12 cull cows at $65 and 42 bobby calves at $8 = $1116).

The budgets, in terms of net farm income (NFI), are summarised in the following equation:

NFI = (milkfat output x price) + stock sales
 - (variable costs + fixed costs) - tax (4)

Estimates of the income-determining random variables, milkfat output and price, were obtained from the model using the simulation procedure outlined above.

For a_1, net farm income is given by the equation:

$NFIa_1$ = (Milkfat output x price) + $1116 - (1910 + 9185) - tax

For a_2, net farm income is given by the equation:

$NFIa_2$ = (Milkfat output x price) $1116 - (1200 + 9185) - tax

The probabilities assigned to the sample of uncertain events in the payoff table (Table 4.5) were all equal, according to the way they were defined at the outset of the analysis. That is, when the probability distributions were reduced to a series of ten occurrences of each uncertain event these were defined as equi-probability events.

4.8 RESULTS OF THE ANALYSIS

The results of the analysis from the Monte Carlo simulation are summarised in Table 4.6. The summer cropping act (a_1) gives a higher level of expected milkfat production but the no-cropping act (a_2) provides a higher expected net income and expected utility.

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(4) The income tax assessments are based on the 1975-76 tax rate and assume exemptions of $500.

Table 4.6 Summary of Expected Payoffs Using Three Criteria

Criteria	a_1	a_2
Expected milkfat (kg)	8871*	8565
Expected net income ($)	1497	1731*
Expected utility	10.95	14.05*

* Denotes the optimum act for each criterion

A study of the range of payoffs for each act, in terms of utility, shows that part of the reason for a_2 being the preferred act is the influence of one payoff of a_1 with a high disutility (Table 4.5). This is a result of a small net loss in income, which is a function of low production of milkfat together with the higher variable costs associated with growing a crop. The farmers utility function for money losses (Figure 4.1) shows that a small money loss gives a high level of disutility.

The dominance of a_2 on the basis of expected net income is due to the higher costs associated with the cropping act outweighing the additional income from the extra milkfat. There is an increase in expected milkfat of 306 kg from having a summer crop (Table 4.6). The maximum gross value of this is about $400 (i.e. 306 kg at $1.342), but this is still less than the extra costs of $710 of growing a crop.

This result is not altered when the payoffs from the two acts are expressed in utility terms. Apart from the single negative payoff of a_1, there is near enough to a linear relationship between net income and utility for there to be no change of the ordering of the two alternatives when the payoffs are measured in terms of the farmer's utility function.

Therefore the analysis points to the farmer's better course of action as being to farm without a crop next summer.

4.9 THE VALUE OF ADDITIONAL INFORMATION

At this stage of the analysis the extension agency can obtain an estimate of the potential value of further information. This is provided by the expected value of perfect information, as defined in Chapter 3, equation 3.10.

From the payoff table (Table 4.5) the expected payoff of the strategy based upon perfect information is defined as \$1799. The expected payoff of the best action, without additional information, is shown in Table 4.6 as \$1731. The difference of \$68 is the expected value of perfect information, $u(x^*)$. This assumes that the utility of money is effectively linear over the range of money values, which is shown to be the case in the analysis of the farmer's alternatives.

4.10 DISCUSSION

The expected value of perfect information, given in the previous section, can be interpreted by the extension agency as an estimate of the potential for advice about a particular decision problem. In the case of this farmer, and the problem under study, the potential for advice to increase the farmer's expected income is measured as \$68.

This would seem to indicate little scope for advice to assist the farmer with the problem.

For the extension agency to be able to use this result in the planning of an extension programme it would need to have an estimate of the expected value of perfect information for several decision problems. This comparison, of the potential value of advice for several problems, would assist the agency to rank the farming problems according to the potential value of an extension programme aimed at helping clients solve the problem.

The expected payoff of the strategy based upon perfect information depends on the acts which have been specified as possible solutions to the decision problem. Therefore, the potential for advice about a particular problem, as indicated by the expected value of perfect information, will depend on the alternatives which have been used in the analysis of the problem. This means that it is important when setting up the decision problem to draw up an exhaustive list of alternative courses of action.

There would have probably been greater potential for advice to assist the farmer with the summer-dry problem if another strategy, that of increasing the herd size, had been included in the analysis. This alternative was discussed with the farmer but he did not see this one as being realistic. He had increased herd numbers several years previously, encountered some problems, e.g. infertility, lower per cow production, and as a result of this experience was reluctant to reconsider a change in the number of milking cows.

Although the results show that the farmer should have preferred the no-cropping act, it seemed more likely from discussion with him that he was intending to grow a summer crop. If this is correct, then either the evaluation of the decision problem was not correct or else the farmer was making a decision which was not consistent with his preferences. If the latter was the case then there is potential for advice to increase the farmer's expected income by an additional $234.

In the latter case, a result such as this, for a sample of farmers, could persuade the extension agency to design a programme which would help farmers to see that a no-crop system was their best alternative for the summer-dry problem.

It is possible that the farmer did make a decision which was consistent with his preferences and that the model used in the analysis of the problem did not adequately represent the dimensions of the farmer's utility function.

The cropping act is the one which maximises expected milkfat and the production of milkfat or some closely related aspected, e.g. milkfat per cow, might be a more important dimension of the farmer's goal than net income. But the small size of the farm, the desire to pay off a mortgage and the need to provide for a young family indicated that net income should be an important part of this farmer's goal.

One of the consequences of growing a crop within a pastorally-based farming system is regrassing of the crop paddocks. The evaluation of the cropping act did not include the longer term benefits which may accrue from new grass paddocks, mainly extra pasture growth and possible extra milkfat production. It was apparent that the farmer expected these longer term benefits from the regrassed paddocks and he was growing the crop on paddocks which he considered to be producing less pasture than some other paddocks on the farm. Therefore, the farmer may have chosen the best course of action if he expected the present value of the extra net income from the regrassing to be greater than \$234.

In order to obtain an estimate of the farmer's expected net income, if the extension agency did not provide additional advice, the two acts were evaluated on the basis of the farmer's existing level of information about the outcomes, given the uncertainties of the problem. This approach required the author to set out a model of the production system and the farmer provided information about the way the uncertain components of the model combined to give a range of outcomes.

Therefore, the results from the evaluation of the decision problem were to some extent dependent on the model of the system as proposed by the author. If this was inadequate in some way this would affect the analysis even though the information obtained from the farmer about the components of the model was correct.

The basis of the model was two production functions, pasture growth as a function of summer rainfall and milkfat output as a function of pasture growth. In both cases the output of the relationship, i.e. pasture growth or milkfat, was defined as a source of uncertainty and the farmer's beliefs about this uncertainty were obtained from him. But it was only possible (because of limited time for the interview) to obtain an assessment of the uncertainty of output for three levels of the random variables and the results are illustrated diagrammatically in Figures 4.6 and 4.7. The step-like production functions are a result of having to assess the uncertainty at only three points on the function and are obviously a simplified representation of the relationships. For example, the 0.5 fractile of the distribution of pasture growth, given a low rainfall, is 14 kg dm per ha (Figure 4.4). This same level of pasture growth can, according to the model, occur with a chance of 0.5 or less for any level of rainfall over this so-called low range, i.e. $<$ 190 mm. This is a wide range of rainfall over which this growth rate can occur with the same probability.

Conceptually, it would seem possible to derive a production function that was a better representation of the farmers knowledge of this relationship by obtaining the same kind of information for a greater number of rainfall levels.

But without this additional information about the production functions it is not possible to say whether it would alter the results of the analyses to the extent of changing the ranking of the two-courses of action.

4.11 SUMMARY

A dairy farmer's expected payoff for the decision problem of how to manage his farm in the face of an uncertain summer rainfall based on the Bernoullian model of decision-making was obtained. It was shown how this could provide the extension

FIG. 4.7 RELATIONSHIP BETWEEN SUMMER RAINFALL AND THE MEDIAN OF THE DISTRIBUTION OF UNCERTAIN SUMMER PASTURE GROWTH

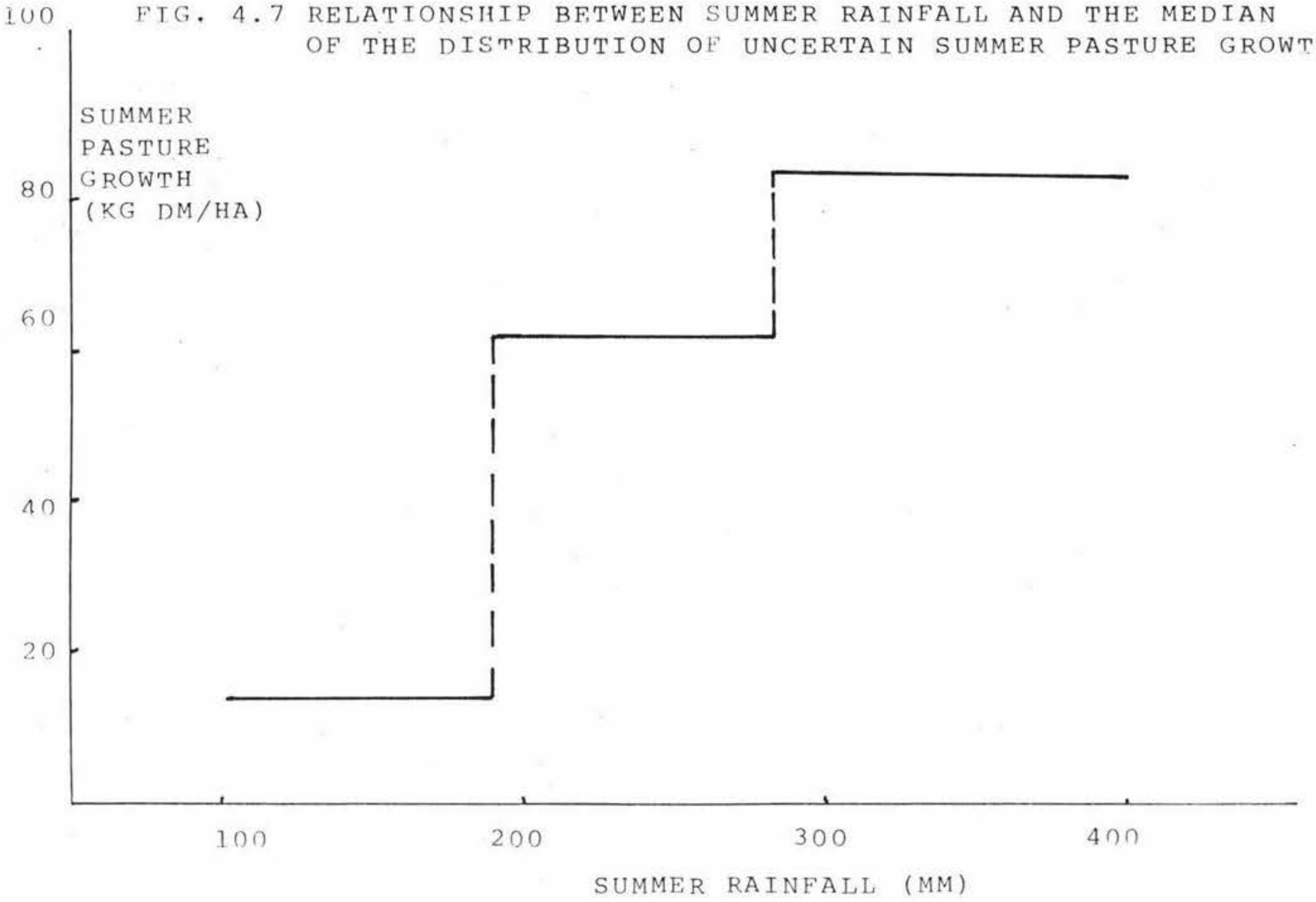
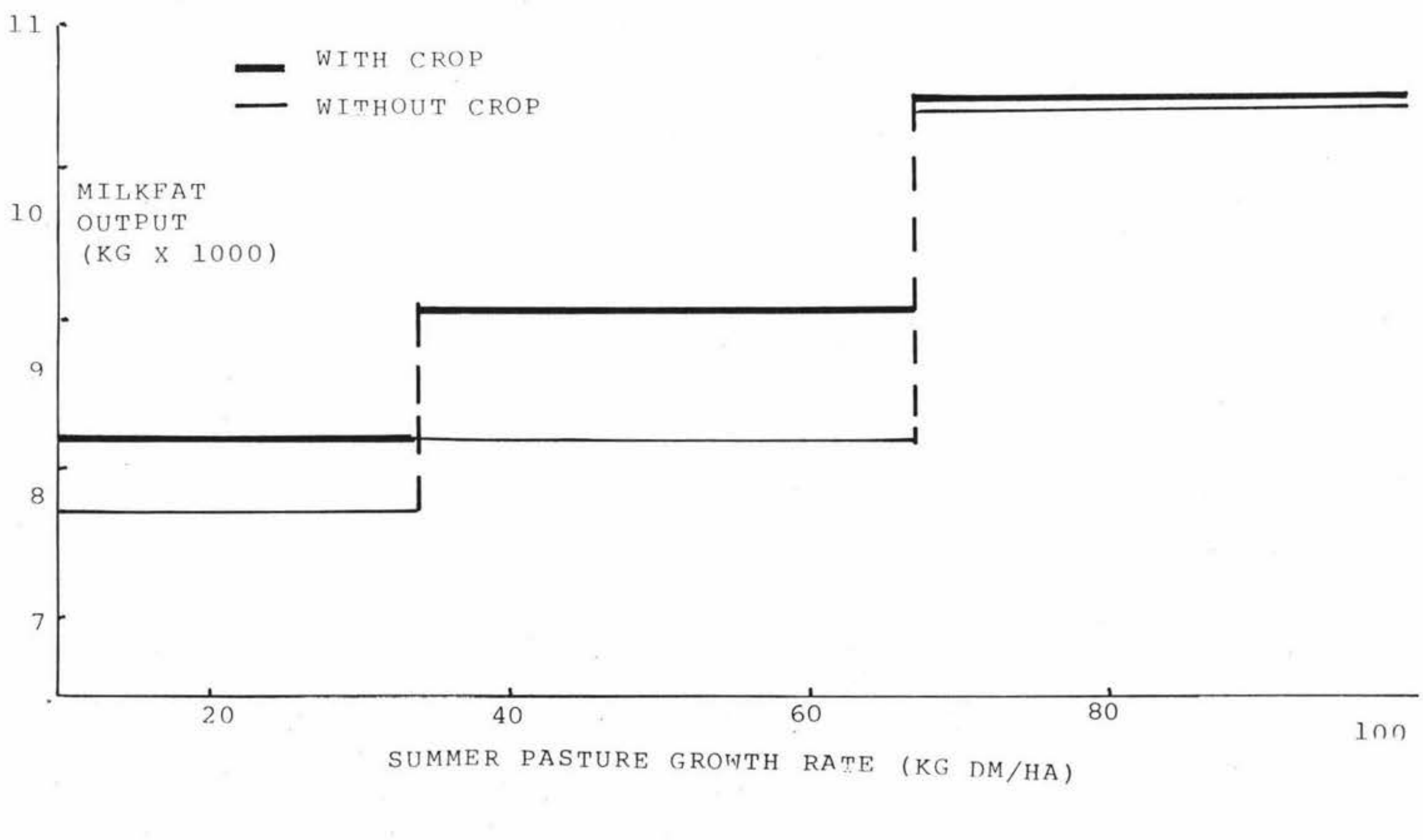


FIG 4.8 RELATIONSHIP BETWEEN SUMMER PASTURE GROWTH AND THE MEDIAN OF THE DISTRIBUTION OF UNCERTAIN MILKFAT PRODUCTION



agency with a measure of the farmer's situation which would be expected to occur without advice, which should assist the agency to estimate the value, to its client, of the information messages applicable to the problem.

The application of the decision theory model to a real farming problem brought out the problems involved in using the model and an estimate was obtained of the potential for advice to assist the farmer with the problem.

5.0 SUMMARY

The extension agency's purpose was defined as to maximise the present value of the change in aggregate farm income subject to the available resources and knowledge.

The agency attempts to achieve its purpose by providing its clients with information that will assist them with their decisions. The problem for the agency is how to make the best use of its resources to provide information or extension messages to its clients.

It was hypothesised that the Bernoullian model of decision-making was applicable to the problem because it would help to make a preposterior assessment of the effects of an extension message on farmer's decisions.

A review of other methods which have been used to evaluate agricultural extension showed that because most have been designed for an <u>ex poste</u> analysis there is the problem of assessing to what extent the benefits have been induced by the extension agency and those which would have accrued anyway.

An interview with a dairy farmer provided data about two courses of action which he considered as the alternatives for managing the farm in the face of an uncertain summer rainfall. Using this data a decision theory model of the problem was developed. This provided a measure of the farmer's expected payoff without any additional information or extension message from the agency. It also provided an estimate, based on the expected value of perfect information, of the potential for further information to assist the farmer with the decision problem. Based on this estimate the agency could infer that there was only limited scope for additional information or extension to assist the farmer.

5.1 CONCLUSION

This research has provided some support for the hypothesis that Bernoullian decision theory does assist the extension agency with the allocation of its resources. It was possible to simulate a farmer's decision problem under uncertainty and to measure the farmer's expected payoff which could be used by the extension agency as a pre-posterior measure of the without advice or control situation.

It was also possible to obtain a measure of the farmer's expected payoff from perfect information which could be used by the agency as a measure of the potential for extension to assist the farmer with the decision problem.

5.2 PROBLEMS WITH THE METHOD

Although the application to an actual farm problem only covered the first part of the proposed method this study has raised some of the problems which may occur in a more complete investigation.

The interviews with the farmer were intended to obtain all the data he was able to bring to bear on solving the problem, prior to receiving any additional information from the extension agency. This took a considerable amount of interview time, 23 hours spread over 5 visits to the farmer, and relied heavily on the farmer's understanding of the problem and its various components.

However, if a model of the production system had been available which incorporated the variables that were the important sources of uncertainty in the decision problem, it would have saved time during the interview. There would be no need to rely on the farmer to define the uncertain events and, given his list of perceived alternatives and beliefs about the outcomes of the uncertain events, the model would assist with the analysis to obtain a measure of the farmer's expected outcome.

Instead, in this investigation it was found necessary during the data-gathering stage to broaden the model in order to include two other random variables which were thought to be important sources of uncertainty. As far as the author is aware there is no well researched model of the dairy cow grazing system which incorporates the variables used in this study as sources of uncertainty.

The shortcomings of the expected value of perfect information as a measure of the potential for advice were pointed out. The problem arises because a particular farmer's list of alternatives is not an exhaustive one. Another farmer may be prepared to consider a more complete list of alternatives as being possible solutions. If there is more variation in the outcomes of the additional alternatives there will be more potential for advice.

However, the usefulness of the expected value of perfect information is more as a means of comparing the scope for advice between two or more decision problems.

The problem of determining whether sufficient weight has been given to non-financial dimensions of the farmer's utility function was encountered in the application. It was inferred from the interview that obtaining a satisfactory level of net income was the most important dimension of utility. But the finding from the analysis of the problem that the farmer preferred the alternative with a lower level of expected utility prompted the suggestion that the farmer may have regarded maximising milkfat production as a more important factor than was evident from the interview. It would seem that there needs to be a more systematic attempt to establish the degree to which non-financial factors contribute to farmer's utility.

APPENDIX I : THE COMPONENTS OF THE DAIRY COW GRAZING SYSTEM

The following is an outline of the components of the dairying cow grazing system which were taken in to account in the relationship between summer rainfall and milkfat production within a farm. There is also a brief review of several estimates of the extent to which milkfat production is affected by variations in summer rainfall.

The variation in summer rainfall affects the level of pasture production which, because it is the major source of feed for the milking herd, affects a dairy farm's output of milkfat for the season. Since milkfat is by far the most important source of income, variations in milkfat production will affect the monetary outcomes of the alternative solutions of the problem.

The liveweight of the herd and the replacement stock may also be influenced by the variation in summer rainfall. This may be reflected in the income from the sale of cull cows and increases in the amount used and the cost of winter supplementary feed.

Hay yields may be affected by the level of summer rainfall and the price of purchased hay may vary depending on rainfall.

The diagram, figure AI indicates the way in which the components of the dairy cow grazing system combine to influence the output of milkfat and the liveweight of the cow. Summer rainfall, together with other components of the system, e.g. soil type, soil fertility, grazing pressure, affect the growth of pasture, which affects the intake of feed by the dairy cow and therefore its liveweight and output of milkfat.

There have been several attempts to estimate the effect of variation in summer rainfall on the production of milkfat. Dean (1975) looked at the relationship between milkfat production in the summer and autumn, rainfall over that period, and stocking rate based on the records of four Taranaki farms for eight years. He obtained a co-efficient of regression for this relationship of 0.85. Dean estimated that irrigation would provide an annual expected benefit of 43 kg milkfat per effective hectare (17.4 kg/cow) assuming that irrigation would be equivalent to milkfat production from the most favourable summer conditions without irrigation. But when the production was compared between summers with the highest and lowest rainfall there was a difference of 115 kg milkfat/ha.

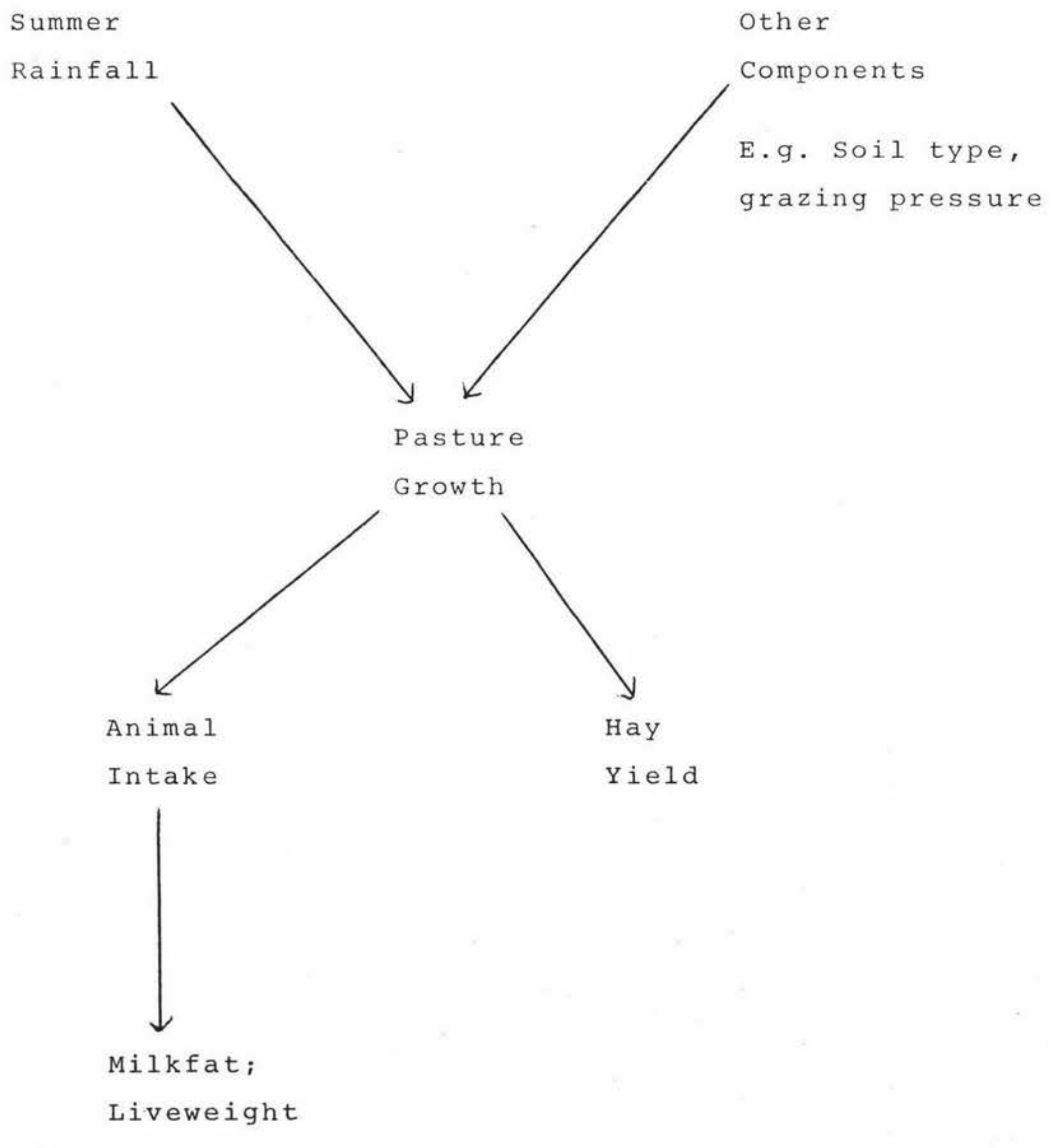
Another estimate of the benefits to be derived from irrigation is provided by Hutton (1974) using trial data from Ruakura No. 5 Dairy. At the stocking rate of 4.9 cows per ha, irrigation produced an extra 22 kg milkfat per cow or 108 kg per ha.

Murray (1973) used milkfat production records from a farm in one of the drier areas of Manawatu to estimate the difference between a good, or almost ideal season and a dry summer as 18 kg milkfat per cow. For a major drought the difference was estimated as 54 kg per cow.

In a paper which discusses the problem of summer drought on dairy farms, Lowe and Halford (1975) quote a figure of 32 kg milkfat per cow as representative of the drop in per cow production in dry seasons.

These estimates of the variation in milkfat production, with summer rainfall provide some indication of the importance of the problem of variation in summer rainfall on dairy farms.

FIG. AI SCHEMATIC REPRESENTATION OF THE COMPONENTS OF THE DAIRY COW GRAZING SYSTEM



APPENDIX II

FIG. AII ANNUAL BUDGETS FOR THE FIRST ACT/EVENT COMBINATIONS FROM THE MONTE CARLO SIMULATION (SEE TABLE 4.5 IN TEXT)

	ACTIONS	
	a_1	a_2
INCOME		
Milkfat 10 650 kg at $1.322	14 079	14 079
Stock Sales	1 116	1 116
Gross Farm Income	15 195	15 195
EXPENDITURE		
Variable Costs		
Seeds - pasture & Crop	110	-
Vehicle Expenses (1)	1 800	1 200
Total Variable Costs	1 910	1 200
Fixed Costs		
Hay bought at 65 c/bale	650	
Other Farm Working Expenses	4 385	
Repairs & Maintenance	500	
Administration	610	
Standing Charges	1 440	
Development-milking plant	500	
Depreciation	1 100	
Total Fixed Costs	9 185	9 185
Total Farm Expenses	11 095	9 735
Net Income before Tax	4 100	5 460
Tax (2)	782	1 646
Net Income after Tax	3 318	3 814

(1) Vehicle expenses reduced by 33% with no-crop action.

(2) The income tax assessments are based on the 1975-76 tax rate and assume exemptions of $500.

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