Risk management for tactical nitrogen fertiliser applications in pastoral farming

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Abstract

The physical and financial outcome from the tactical application of nitrogen fertiliser in pastoral farming is always uncertain. A management policy is therefore required to minimise uncertainty. Listing the sources of production, price and financial risk for nitrogen fertiliser inputs and identifying management actions that mitigate these creates awareness of risk and indicates where management effort can be focused. Data obtained from traditional pasture response research trials are not well suited to decision-making at the farm level. However, results obtained using an expert knowledge approach demonstrated that response relationships for nitrogen can be generated in a form which is more applicable to decision-making situations faced on farms. These data can be adapted to a decision tree framework which allows the likelihood of uncertain events to be formally incorporated in the estimation of financial returns for alternative application decisions for nitrogen fertiliser. A bull beef example showed that highest returns for different weather scenarios were consistently obtained for the application of 50 kg N/ha (as urea), rather than 0 or 25 kg N/ha.

Keywords: economics, fertiliser, nitrogen, pastures, risk

Introduction

Pasture and animal responses to nitrogen (N) fertiliser applications can be highly variable, especially during autumn, and this may be the reason why the use of N fertilisers on New Zealand hill country is relatively low (Tillman & Gregg 1992). However, it is generally possible to identify the variables that give rise to this uncertainty, and as a consequence it is also possible to develop management strategies that reduce the risk of unsatisfactory outcomes when N fertiliser is used. The purpose of this paper is to quantify and rate the sources of uncertainty associated with N fertiliser use, and to develop a management framework based on decision-tree analysis (Nelson *et al.* 1978) that can be used by farmers to estimate the likely production and financial consequences of different application dates and rates for N fertilisers. This approach can be contrasted with more sophisticated risk simulation techniques such as that described by McCall *et al.* (1992). Deficiencies in existing research data for N fertiliser use at the farm management level and an alternative method of generating this information using the knowledge of expert scientists are also discussed.

Sources of uncertainty in N fertiliser decisions

Perfect knowledge is rare in decision-making in agricultural systems. Inevitably, elements of risk and uncertainty exist because of the linkages of agriculture to biological systems and the global economy. Knight (1921) distinguished between risk and uncertainty on the basis of the availability of historical or statistical data to predict the probability of outcomes (risk) and the determination of the likelihood of events occurring on the basis of (previous experience and intuition (uncertainty). In everyday practice, however, the terms risk and uncertainty are usually used interchangeably.

The sources of risk associated with N fertiliser decisions for pastoral livestock systems can be categorised as being production, price (or market) or financial (Martin 1994). Production risk arises from the variability inherent in the biological processes of pasture growth and the conversion of this into animal products. Price risk occurs because of fluctuations in the value of purchased inputs (such as N) and saleable outputs, while financial risk arises from the ability of the farm business to meet prior claims on the cash generated by the farm. The combined effects of production and price risk is sometimes called business risk, and this is reflected in the variability of the cashflow for the farm business (Martin 1994).

The first step in managing risk, whether it is N or some other aspect of the farm business, is to identify the sources of risk and to determine which of these can be subjected to management control. Thus, Martin & Lee (1990) suggest that differences in the response of farmers to uncertainty may be attributed to their relative awareness and ability to assess sources of uncertainty. Table 1 summarises the main elements that contribute to production, price and financial uncertainty in relation to N fertiliser use on pastoral livestock farms and also indicates management actions that can ameliorate these sources of risk. For example, a management action involving the selection of a paddock with fertile soils and a ryegrass dominant sward is likely to reduce the risk of an unsatisfactory response from N compared with an application made to a low fertility site with a browntop dominant sward. It should be noted that the assessed levels of risk for some of the variables shown in Table 1 depend on whether the farmer regularly collects and analyses data about possible sources of risk. The ratings for site conditions, weather and spreading, for example, are likely to shift to high (H) if data on soil temperature and the likelihood of heavy rain soon after application was not determined (Parker et al. 1989).

Table 1 indicates that uncertainty associated with N use is greatest in relation to production because of the pattern and variability of pasture and animal response. Price risk is relatively low when saleable products arising from the tactical use of N are sold within 3-4 months of application but may increase where the outputs are not sold until 6 months or more after a N application. However, long-term financial benefits may also be obtained through improved lifetime production of heavier replacement animals (Parker *et al.* 1989). Factors associated with weather (including season) give rise to the major sources of production risk in relation to N decisions (weather may also influence livestock and fertiliser prices in terms of the seasonal availability of pasture and fertiliser).

Production risk can be reduced by the farmer adopting a monitoring programme to measure rainfall and 10 cm soil temperatures (daily) and soil fertility (every 2-3 years). In addition, 7-day forecasts of expected weather events around the planned date of application should be obtained and both the fertiliser and contractor (or necessary machinery if the farmer does the spreading) should be arranged 3-6 weeks prior to the expected time of application to minimise the risk of not being able to apply N at the optimum time. This type of forward planning requires the preparation of tactical feed budgets to assess the likelihood of feed shortages occurring (Field & Ball 1978), rather than a 'knee-jerk' reaction to an actual feed shortage. Feed planning should be paralleled with financial budgets that assess the likely returns from increasing animal output through the use of N (Parker *et al.* 1989).

Table 1 Sources and assessed levels (L=Low, M=Medium, H-High), of production, price and financial uncertainty associated with the decision to apply N fertiliser and management actions which can minimise the likelihood of an unsatisfactory outcome.

Source of uncertainty	Assessed Level	Management actions to minimise risk
Production		
Site conditions		
• pasture composition	L	Select grass dominant, improved swards.
• soil fertility	L	Select medium to high fertility paddocks.
• slope	L	Select flat to rolling topography.
Weather		
• rainfall	M-H	Apply during or immediately prior to light rainfall but avoid heavy rainfall events within 3-4 days of application.
• soil temperature	M	Apply when soil temperatures at 10 cm exceed 6ºC (and will remain above this temperature for at least 4 weeks).
Time of application		
• spreading	L	Pre-book fertiliser spreading contractor where own equipment is not available.
• season	M-H	Size and reliability of response: spring > autumn > winter.
Animal utilisation		Select soil conditions to minimise pugging; allow pasture to grow to optimum length for DM production and maintain at this level.
Price		
Fertiliser		
• availability of material	L	Forward plan (4-6 weeks) to anticipate requirements.
• seasonal supply	L	Book expected requirements early.
• product quality	L	Buy registered and reputable products; cost N component for alternative N fertilisers.
Animal products		
• sheep	L-M	Forward contract lamb or wool
• beef	L-M	Forward contract. Utilise feed with growing young animals, rather than for maintenance.
• dairy	L	Minimum milk prices are known at time of application.
Financial[a]	L	Establish current equity and liquidity position of the farm business. Forward plan cashflow with additional N fertiliser expenditure.

[a] Largely dependent on the farm debt to asset ratio, the business management practice and the stance of the lender (where funds are borrowed).

Limitations of current research data for risk management

While a large number of pasture response trials have been conducted with N fertiliser in New Zealand, relatively few have generated information in a form that is directly applicable to risk management at the farm level. Deficiencies in the reported results include: inadequate information about site and weather conditions at the time of, and subsequent to, N fertiliser application; results expressed simply as a total DM response to N rather than also as the temporal distribution of extra DM production; limited information on animal responses following N application; and a relatively narrow range of site conditions and application dates, especially in relation to hill country pasture. It would be cost-prohibitive, however, to conduct the full series of experiments that are necessary to generate the input-output relationships (Wragg 1970) required for economic evaluation and management decision making. An alternative low cost method of obtaining these data is to use 'experts' to define, on the basis of their substantial research experience with N fertilisers, the nature of the pasture response function to N under different field conditions (Wright 1993). Examples of the data generated by this means through a mail survey and interview of 12 expert scientists are summarised in Tables 2 and 3. Pasture response data in this form can more readily be incorporated in a risk analysis framework to assist management decision making.

Table 2 Estimates by expert scientists of the effects of changes in climatic conditions on pasture responses to urea fertiliser applied at 25 kg N/ha on 1 August to a sward with 1500 kg DM/ha. Figures in brackets are the total response relative to 'average' conditions (Source: Wright 1993).

	Pasture response (kg DM/kg N)				
		Days after application			
Climate	Total	0-30	31-60	61-90	91-120
Standard[a]	11.6 (100)	5.8	3.8	2.3	-0.3
Wet (50 mm within 24 hrs of application)	9.3 (79)	5.3	3.0	1.0	0.0
Cold (6-8°C)	7.1 (59)	3.0	2.3	1.5	0.3
Warm (IO-11%)	12.3 (104)	7.2	3.3	1.8	0.0

[a] The standard conditions were defined as 25 kg/N/ha applied as urea to a ryegrass:browntop:clover pasture (60:25:15) on 1 August when soil temperatures at 10 cm were 8% and rising.

Table 3 Estimates by expert scientists on the effects of nitrogen (N) application rate (as urea), grazing management post-application and herbage mass present at the time of application on pasture DM responses to N.

	Pasture response (kg DM/kg N)				
		Days after application			
Variable	Total	0-30	31-60	61-90	91-120
Standard conditions[a]	11.6	5.8	3.8	2.3	-0.3
Application rate					
50 kg N/ha	10.3	5.0	3.5	1.8	0.0
100 kg N/ha	7.3	3.1	2.1	1.5	0.5
Grazing management					
set stock	4.3	3.5	1.8	0.5	0
rotational graz	13.0	7.0	4.5	1.5	0
Herbage mass					
750 kg DM/ha	a.5	3.5	3.3	1.8	0
2200 kg DM/ha	13.5	7.5	4.3	1.8	0

[a] See Table 2; Rate = 25 kg N/ha, rotation commenced 21 days after application, 1500 kg DM/ha at application.

Risk analysis using a decision tree approach

An example decision tree analysis for a bull beef farmer considering the application of N in spring (say 1 September) is outlined in Figure 1. The decision is simplified to 'At what rate (0, 25, 50 kg N/ha) should N (urea) be applied?' but further branches could be added to consider alternative application dates and the utilisation of pasture. Potential weather conditions within the first three weeks of application are classified as 'favourable', 'normal' or 'unfavourable'. An analysis of 10 years of weather records for the local area indicate that the probability of these conditions occurring is 0.2, 0.6 and 0.2, respectively (alternatively a farmer could estimate these values subjectively). The extra pasture production (over 90 days) resulting from the input of N under these weather conditions is described in Table 4. It is assumed that 100% of the pasture is utilised by bulls, which weigh 420 kg at the time of urea application, but it is possible that N inputs could generate feed surplus to animal requirements and this could lead to lower pasture quality and lower net returns. A spreadsheet simulation model for bull beef growth (Wright 1994) was used to estimate bull liveweights at the end of November and hence carcass weights (Table 4). These data indicate that applying 25 kg of N (or more) per ha in unfavourable conditions would compensate for lost production relative to a normal year, and that the application of 50 kg N/ha in a normal year would provide a similar animal production response to that achieved from 2.5 kg N/ha applied in a favourable year (Table 4).

Table 4 Calculated pasture production, bull liveweight gains and final carcass weight resulting from of a decision to apply 0, 25 or 50 kg N/ha if weather conditions for pasture growth are favourable, normal or unfavourable. Changes for each parameter are expressed relative to a normal weather situation with no N. Figures in brackets are the respective base values.

	N application rate (kg N/ha)		
	0	25	50
Pasture production (kg DM)			
Favourable	112	420	616
Normal	0(728)	252	420
Unfavourable	-140	0	84
Liveweight gain (kg/d)			
Favourable	0.08	0.30	0.44
Normal	0(0.50)	0.28	0.30
Unfavourable	-0.10	0	0.06
Carcass weight (kg)			
Favourable	4	14	21
Normal	0(231)		14
Unfavourable	-4	3	3

The payoffs for each alternative (Figure 1) show that the highest marginal net revenue is generated by the 50 N option for normal and favourable weather conditions, but that the 25 N option would provide the lowest loss in returns in unfavourable weather conditions. Returns for carcass weight in the 220-245 kg range are assumed to be $2.70/kg, compared with $2.77/kg for carcasses in the 246-275 kg band. Growing animals to a higher priced schedule value, which occurs with the 50 kg N/ha application under favourable conditions, therefore importantly influences the financial returns from N (a similar situation would occur through growing lambs into a higher value weight range and grade).

Decision criteria which can be applied to the payoff information given the probabilities of the weather events include minimum regret (a risk averse farmer), the maximax option (risk taking) and maximum expected monetary value (EMV) (risk neutral) (Halter & Dean 1971), but farmers may also have other decision criteria. For the bull beef example, each of these criteria would result in the decision to apply 50 kg N/ha. The effect of different probabilities of weather conditions occurring on the EMV is shown in Table 5. This indicates that the application of 50 N would remain the 'best' option even if there was a 70% chance of unfavourable weather conditions after urea application. The break-even animal production response (LWG/bull) necessary to recover

Figure 1 Decision tree analysis for the application of 0, 25 or 50 kg N/ha to pastures for bull beef production under different spring weather conditions.

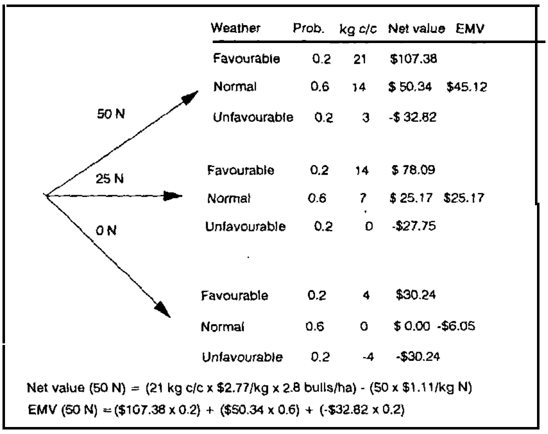

Table 5 Effect of alternative probabilities of weather conditions occurring on the expected monetary values (EMV) of a decision to apply 0, 25 or 50 kg N/ha.

Weather	Probabilities of weather events		
Unfavourable	0.2	0.5	0.7
Normal	0.6	0.4	0.2
Favourable	0.2	0.1	0.1
EMV($)			
0 N	-6.05	-15.12	-21.17
25 N	25.17	4.00	-6.58
50 N	45.12	14.46	-2.17

the cost of urea is 0.80 kg ($1.1 l/kg N//$2.70 kg carcass, 52% dress out).

Conclusions

The low use of N fertilisers by some farmers, especially in the sheep and beef cattle sector, suggests that they regard the risk of an unsatisfactory pasture/animal response, and hence the likelihood of generating a profitable return, as being high. However, as outlined in this paper there are a number of practical, and relatively simple, steps that can be taken to minimise this risk. These include identifying the sources of risk, monitoring soil, pasture and weather conditions, and the use of a decision tree framework to systematically evaluate management alternatives. While spreadsheet models were used to generate the animal liveweight data in this study, farmers (or their consultants) could directly estimate values on the basis of prior experience.

An estimate of the breakeven animal production response would provide further support to this analysis.

ACKNOWLEDGEMENT

We thank the scientists from AgResearch and Massey University who participated in the expert knowledge survey.

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