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# **Production and Marketing Risks Management System in Grazed Systems: Destocking and Marketing Algorithm**

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Additional information is available at the end of the chapter

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## **Abstract**

This study was carried out to explore potential approaches to managing production and market risks associated with climatic variability in dryland grazed systems. The methodology is novel in that it considers farmers' ability to make sequential adjustments to their production activities when information on uncertain events becomes available. Traditional approaches to evaluation of farmers' response to risk assume perfect knowledge of production resources and that risk emanates from uncertainty in yield returns. Strategic approaches are mostly considered in evaluating farmer's risk attitude implying that managing the variability (risk) assumes that different production activities resource requirements are known (non-embedded risk). In real farming systems, the producers make sequential decisions and adjust the timing and methods of their activities as a season progresses and more information on uncertainty becomes available (embedded risk). This chapter describes a platform adopted in making destocking and marketing decisions by simulating the impact of implementing alternative tactical adjustments. The algorithm was successfully tested in a research that investigated the physical and economic impact of incorporating tactical responses in risk management strategies in dryland sheep production systems in New Zealand. The algorithm can be integrated into existing grazing models and can also be used as a standalone system.

**Keywords:** embedded risk, climatic variability, tactical adjustments, dryland grazing systems, algorithm, risk management strategies

# 1. Introduction

## 1.1. Background information

The overall objective of grazed systems is the maintenance of high animal and pasture performance as it results in optimization of enterprise production and profitability. In dryland systems, this is complicated by the need to balance the fluctuating animal feed demand as well as pasture quality and quantity [1]. Setting stocking rate (SR) is the principal managerial decision in these systems [2] but a variety of other short- or medium-term management options (tactical responses) are available [3]. The most commonly used strategy in managing the effects of climatic variability in dryland grazed systems is understocking [4]. This results in lost opportunity of increased profitability in better than average seasons (when feed supply exceeds demand). Conversely, high stocking rate increases risk in such a variable environment especially so in worse than average seasons (when there is feed deficit). In order to mitigate the challenge of fluctuating feed demand and supply, there is a need for the inclusion of a series of options which provide the flexibility to alter feed demand, and to a lesser extent supply, in response to changes in climatic conditions during the season.

The study [5] from which this chapter was extracted from indicated that incorporating a framework to implement such options would result in physical (in terms of pasture utilization) and economical (enterprise profitability) benefits. The findings from the study by Gicheha et al. [5] indicated that all strategies incorporating tactical responses were economically superior to those which did not. In some instances, the difference in GM between corresponding strategies with and without including tactical adjustment to climatic variability was as high as 39.65%. In all cases, corresponding risk management strategies incorporating tactical responses to climatic variability resulted in higher gross margin (GM) ( $P < 0.05$ ) and lower risk ( $P < 0.05$ ). The extra income derived from including tactical responses can be viewed as the cost to the farmer of basing choice regarding a management strategy on analysis that neglects the tactical advantages afforded by such a strategy. This chapter describes a destocking and marketing algorithm integrated into a grazed system model (LincFarm; [4, 6]) to implement tactical adjustments to climatic variability in a dryland grazed system in Canterbury Plains in New Zealand. The algorithm is implementable in any grazed system as an integral part of the model or a standalone subsystem.

## 1.2. Risk analysis

Risk from the dictionary perspective is the possibility of incurring misfortune or loss.<sup>1</sup> According to Ref. [7], the risk is defined as the possibility of adversity or loss, and referred to risk as “uncertainty that matters”. A study by Kay and Edward [8] further defined risk as a situation in which more than one possible outcome exists, some of which may be unfavorable. However, it was [9] who provided the three common interpretations of risk as a chance of a bad outcome, a variability of outcome and uncertainty of outcomes. Considering risk as a chance of a bad outcome implies the

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<sup>1</sup>Collins Concise Dictionary, 3rd edition, 1995.

probability of some undefined unsatisfactory outcome occurring. For example, assuming there is a single measure of outcome denoted  $X$  much of which is always preferable to less. The chance of bad outcome definition could be represented by the following probability:

$$P^* = p(X \leq X^*) \quad (1)$$

where  $P$  is probability,  $X$  is the uncertain outcome, and  $X^*$  is some cut-off or minimally acceptable outcome level below which outcomes are regarded as 'bad' and  $P^*$  denotes the probability of  $X^*$  occurring. In some cases, the value  $X^*$  might reflect some disaster level such as 'insolvency;' however, more often this may be a less clear-cut notion, with application of this measure of risk favoring specification of the two parameters  $P^*$  and  $X^*$ .

The interpretation of risk as variability can be measured statistic of dispersion of the distribution of outcomes, such as the variance ( $V$ ) or standard deviation ( $SD$ ) of the uncertain outcome [9]:

$$V = V[X] \quad (2)$$

or:

$$SD = \sqrt{V} \quad (3)$$

However, neither  $V$  nor  $SD$  provides information on the location of the distribution of outcomes on the  $X$  axis necessitating use of the dispersion statistics to link  $V$  or  $SD$  with the mean or expected value ( $E$ ) as follows:

$$E = E[X] \quad (4)$$

Variance may then be described as the risk around the specified mean. The study by Newberry and Stiglitz [10] extended the notion to reflect risk using the coefficient of variation ( $CV$ ) of  $X$ :

$$CV = \frac{SD}{E} \quad (5)$$

In order to define risk as the distribution of outcomes the whole distribution of  $X$  needs to be specified with a complete specification requiring the probability density function,  $f(X)$ , or equivalent and often more conveniently, the cumulative distribution function  $F(X)$ . However, in practice, summary statistics including moments are commonly used to describe the probability distribution. This means that there is some similarity with the measurements based on the definition of risk as dispersion. In such cases as the normal, the distribution of outcomes is completely defined by only the mean and variance. Few other distributions might be approximated in terms of mean and variance, though higher order moments may be needed to clearly describe the shape of the distribution.

The limitation of defining risk as a chance of a bad outcome or variability of outcome [3] and their associated measures is that neither gives the whole picture especially when a choice has to be made among many risky alternatives. In regard to risk as a chance of a bad outcome, it is

evident from observing behavior that not all risks with bad outcomes are rejected. For example, many people travel by car to sightseeing with the knowledge that there is increased probability of death or serious injury in case of a road accident. Apparently, choices with chances of very bad outcomes such as death or serious injury are at times accepted, assumingly because the benefits of the up-side consequences such as seeing interesting sights are sufficiently attractive to offset the relatively low chances of the bad outcome. Subsequently, to evaluate or assess a risk, there is need to consider the whole range of possible outcomes, good and bad, and their respective probabilities. Thus, as suggested by Hardaker [9], expressing risk in terms of only the probability in the lower limit of the distribution of outcomes does not provide full information for proper risk assessment and may thus be seriously misleading.

Different studies have considered risk and uncertainty with varied reactions and have defined them differently [10]. For instance, Knight [11] suggested an existence of three states or 'categories' of knowledge in decision-making situations: perfect knowledge, risk, and uncertainty. The suggestion was that risk is variability of an outcome with known probabilities, while uncertainty is variability of an outcome with unknown probabilities. Other authors such as Anderson et al. [12] recognized little difference between risk and uncertainty by Arguing that all probabilities in decision-making are subjective, and thus, the difference between risk and uncertainty becomes insignificant. In this chapter and the study from which it was extracted from, risk and uncertainty are treated as the same; risk and/or uncertainty are considered in general as the variability of outcomes, that is, the converse of stability and are referred to as either risk or variability. This has a significant impact on what constitute good climatic variability management strategies to be considered and good risk management in general.

### 1.3. Sources and responses to risk

Various potential sources of risk in agriculture have been identified. Risk was summarized into production, price or market, currency, institutional, financial, legal, and personal by MAFF [13] while Waterman [14] classified sources of risk into five categories as production, marketing, financial, legal or human resource. Production risk comes from the unpredictable nature of weather and uncertainty about the performance of crops and/or livestock, while marketing risk refers to the uncertainty of prices of farm inputs and outputs. Farmers are increasingly being exposed to unpredictable competitive markets for inputs and outputs [13]. Currency risk as noted in Ref. [13] relates to the revaluation or devaluation of the national currency which affects export and imports demand and domestic prices for competitively traded inputs and outputs. In countries where agriculture is export, oriented currency risk is considered an important aspect when designing a farm model.

There are a number of basic responses to risks in agriculture that have been identified. A decision-maker can respond by accepting the risk, transferring the risk via insurance or contracts, or by eradicating or managing the risk by putting in place risk reduction strategies. The work by Waterman [14] suggested five responses to risk as retain, shift, reduce, self-insure and avoid, while the study by Barry [15] had summarized risk responses into four basic categories as either being production, marketing, financial or integrated. Examples of production risk responses include development of a decision support system for predicting seasonal rainfall



variation [16] and a decision support system on the impact of planting drought resistant pasture [17] in management of climatic variability. Similarly, various marketing risk response options exist, and examples include forward contracting with the buyer of the crop or live-stock, spreading sales throughout the season, or hedging [18]. A financial response could be to carry a large cash reserve to protect the business from a failed crop or a poor season. An integrated response would be a combination of any or all of the listed responses. In managing climatic variability in high-performance dryland sheep systems, a range of alternative risk management options was explored.

All risk responses, however, come at a cost [19]. For instance, a decision to forward contract the sale of animals could mean that if the price of the increases, the farmer would be losing out on potential extra income. The decision to carry a large cash reserve or to limit the level of borrowings may limit the potential rate of growth of the business. It is this complexity in decision-making that emphasizes the need for simulation models to evaluate and identify optimal strategies. For a farm model to be relevant, it should account for such tactical responses to risk to optimize productivity and profitability. This is the main focus of this chapter.

#### 1.4. Resilience

Resilience was defined as the ability of a system such as the ecosystems, societies, corporations, nations and socio-ecological systems to undergo a disturbance and maintain its functions and control by Gunderson and Holling [20]. They considered resilience as a measure of the magnitude of disturbance a system can tolerate and still persist. This is different to the concept previously advanced by Pimm [21] as a system's ability to resist disturbance and the rate at which it returns to equilibrium following disturbance. The study by Holling [24] observed that the distinction between the two definitions of resilience has been useful in encouraging the managers of naturally variable systems such as the dryland pastoral systems to move away from concentrating on management aimed at the unachievable goal of stability. However, it is important to simultaneously consider resistance which is a complementary aspect of resilience and is defined as the amount of external pressure needed to bring about a given amount of disturbance in the system by Carpenter et al. [22].

According to climate change research by Crawford et al. [23], farmers will continue to encounter increasing climatic extremes, and it is important therefore to design farming systems that will cope with the increased climatic extremes and variability. Resilient farming systems would take advantage of the three properties conceived by Holling [24], that is the amount of change the system can undergo and still retain the same functions and control, the degree to which the system is capable of self-reorganization, and the degree to which the system can build the capacity to learn and adapt (such as use of available information and tools in implementing flexibilities in dryland pastoral systems). These three properties have been explored further by Rusito et al. [25] who identified buffer capacity, adaptive capacity, and transformability as three elements that allow the manager to respond to different degrees of change in the production environment. Buffer capacity is defined as the constancy of system productivity when subjected to small disturbances as a result of fluctuations and cycles in the production

environment in Ref. [26]. Adaptive capacity was defined by Brooks [27] as the capacity of a system to respond to a change or shift in the environment to cope better with existing or anticipated external shocks [22], however, do not distinguish between resilience and adaptive capacity and have used these terms interchangeably. Transformability was defined by Darnhofer et al. [28] as the ability of a manager to find new ways of organizing resources when the disturbance in the production environment is extreme enough to compromise the current system.

The work by Rusito et al. [25] recognized that resistance, described by Carpenter et al. [22] as the amount of external pressure needed to bring about a given amount of disturbance in the system, measured as efficiency, the degree to which the system is capable of self-reorganization [24] measured as liquidity, and vulnerability which was defined as the potential for loss by Luers et al. [29] and measured as solvency in Ref. [23] are useful indicators of buffer capacity. Highly efficient systems are characterized by higher resistance, and that farms with good liquidity have more ability to reorganize themselves (return to the original state) following a shock as noted by Rusito et al. [25]. In a study of the resilience of New Zealand dairy farm business from 2006 to 2009, a period characterized by wide fluctuation in milk price [16], observed that farmers who took best advantage of upside price risk did not cope well with downside price risk. This implies that the portfolio of risk management strategies used by farmers to respond to upside price risk did not align well with downside price risk management. Their study underlines the importance of risk management portfolios whose strategies take advantage of the upside risk while at the same time minimizing downside risk.

The research whose findings are presented in this chapter was set to take advantage of both upside risk (stock for better than average growing conditions) and downside risk (retreat by sale of animals as and when conditions dry out) resulting from climatic variability. Alternative risk management portfolios are identified (in the form of risk-efficient strategies) from which farmers with different production objectives and preferences can choose. The portfolios differ in pasture types and combinations, flexible stock class combinations (saleable animals maintained in the system), and soil moisture levels to trigger stock sale decisions.

### 1.5. Risk management

Risk management as defined by Landcare Research [30] is the culture, processes, and structures that are directed toward the effective management of potential opportunities and adverse effects. In an agricultural setting, risk can be defined as choosing among alternatives that reduce the financial effects of the uncertainties of weather, yields, prices, government policies, global markets, and other factors which can cause variations in farm income [13].

It was suggested [31] that as all actions that might be taken by a farmer are subject to risk, there is no distinction between farm management and what is historically called risk management. In many ways, all decisions made in agricultural systems are made with imperfect knowledge about the outcomes. A crop is selected, sown, managed and harvested in weather conditions that are uncertain at sowing. A yield of unknown quality is harvested and after which, the product is then sold at what may be an unknown price. These unknowns make efficient resource allocation decisions difficult. Since agricultural production occurs in a risky environment, there is

a need to make decisions on how to manage the risk. Until mid1990s, priority with respect to analyzing risky decisions has been placed mostly on choice of farming strategy and on accounting for the effects of attitude to risk [32, 33].

A decision tree obtained from Ref. [9] is presented to describe the effects of attitude to risk on choice of strategy. The decision tree (**Figure 1**) represents three stocking options, to buy 300, 400 or 500 steers. The next step in the decision tree relates to factors outside the farmer's control, the weather in this case for which it is assumed there are just three scenarios resulting in good, average, or poor growth. The probability of good growth is 0.2, of average growth 0.5 and of poor growth 0.3. For each of the three stocking options and the three possible weather circumstances at their probabilities, there is a net return. The net return range from \$34,000 where 500 steers are purchased and favorable weathers follow to a loss of \$10,000 where 500 steers are purchased and the weather condition is not favorable.

The possibilities of each weather condition multiplied by its corresponding net return give the expected value of that strategy. In the case presented here, the strategy with the highest expected value is that of purchasing 400 steers. Although it would be seen as the best in terms of expected value, it does not account for risk attitudes or some other influential factors which can have a direction in decisions made. For example, with this strategy, there is a 0.3 probability of earning \$0, which may cause harm to the business. The option of buying just 300 steers always results in a positive return, but the corresponding returns are smaller compared to the positive returns probable from the other two options. The optimal choice for a given individual may not necessarily be the strategy with the highest expected value, relative to the individual's attitude to the possible outcomes, such as making a significant loss.

### 1.6. Farmer risk attitudes and preferences

Risk attitudes are typically divided into just three categories, risk-neutral, averse and risk-loving. A risk-neutral person would be expected to choose the strategy with the highest expected value regardless of the variations of possible returns, that is, choose the option of purchasing 400 steers from the decision tree presented in **Figure 1**. Conversely, risk-averse individuals exhibit a willingness to accept a lower expected return so as to avoid the opportunity of unfavorable outcomes. As presented in **Figure 1**, the chance of earning \$0 or making a \$10,000 loss may be unacceptable and the option of purchasing 300 steers although resulting in a lower expected return may be preferable [8]. However, risk-aversion does not necessarily mean that individuals are not willing to take risks. Rather it means that individuals must be compensated for taking the risk and that the required compensation must increase as the risk and/or the levels of risk-aversion increase.

To be more useful, agricultural models should account for risk and the risk attitudes of farmers. The work by Pannell and Nordblom [34] recognized the need for models to account for risk and the risk attitudes of farmers to be considered useful. In their report on the effect of risk aversion on whole farm management in Syria, they found significant effects in terms of farming policies related to risk attitudes. Different approaches [35, 36] have been used in describing risk in agriculture: the expected value and utility approaches and models (e.g. [37, 38]), heuristic safety-first approaches (e.g. [12, 37]), farmers' risk aversion [38, 39], and the



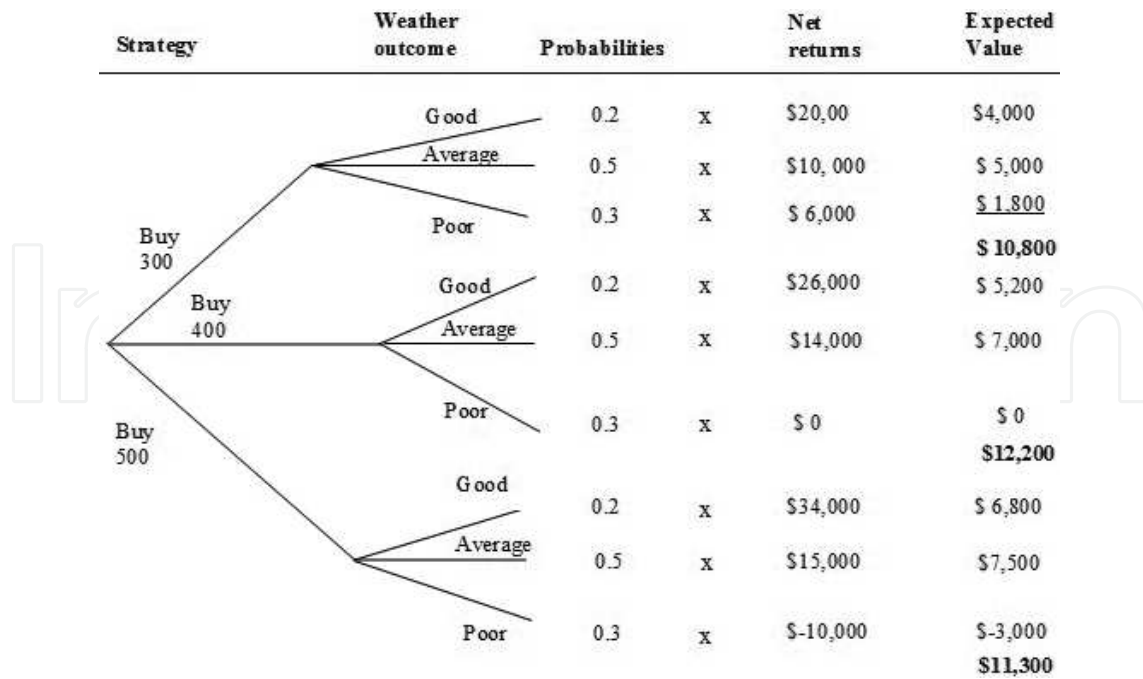


Figure 1. Decision tree (Source: Kay and Edward [8]).

effect of risk on farmers’ resources [40]. Traditionally, farming systems were modeled with regard to risk attitude, thus assuming decision-makers to be either averse or neutral, or generally just assuming risk aversion, using some measure of preference such as subjective expected utility (SEU) [41]. The SEU hypothesis involves breaking down risky decision problems into separate assessments of the decision-makers beliefs about uncertainty, captured via subjective probabilities, and the decision-makers preferences for consequences, obtained via a utility function, the two parts are then recombined to select as optimal the decision which yields the highest expected utility or certainty equivalent (CE). Generally, the SEU hypothesis provides the best operational basis for structuring risky choices.

1.6.1. Utility and expected value

To explain utility and expected value, assuming there are just two possible choices, one with a greater expected value than the other, that choice with the greater expected value is the best. However, if the option with the greater expected value has two possible outcomes, one of great profit as well as one of great loss, and the second possible choice has a lower expected value, with neither of the two potential outcomes resulting in a significant loss, the second possible choice may be preferable to some people which introduces the concept of risk attitudes and utility [36].

A sample demonstration decision problem was used by Hardaker et al. [36] in which there was a once-only choice to be made between options a1 and a2, with consequences depending on two equally likely uncertain events s1 and s2 to explain the economic concept of utility. This is presented in Table 1 below.

$S_i$	$P(S_i)$	$a_1$	$a_2$
$s_1$	0.5	1000	500
$s_2$	0.5	0	500
EMV <sup>1</sup>		500	500

<sup>1</sup>See text for description.

**Table 1.** Economic concept of utility example.

A risk averse individual will prefer  $a_2$  to  $a_1$ , whereas a risk preferrer will chose  $a_1$  to  $a_2$ . Ordinarily, any person indifferent to risk would base their choice on the expected monetary value (EMV) therefore portraying indifference between the two options. Assuming that there is a progressive reduction of the \$500 payoffs represented by choice  $a_2$ , there would come a point where the risk adverse decision maker is indifferent between options  $a_1$  and  $a_2$ . Presume that the certainty equivalent (CE) for some individual is \$450 in the example above. It can be said that the utility of the risky prospect  $a_1$  is equal to the utility of the \$450 CE for this person. Based on arguments presented above, it can be shown that utility function,  $U$ , exists and exhibits the properties that:

$$U_{(a_1)} > U_{(a_2)} \quad (6)$$

From Eq. (1), utility function  $U$  exists only if  $a_1$  is preferred ( $>$ ) to  $a_2$  and that the utility of a risky prospect is its expected value (E):

$$U_{(a_1)} = E[U_{(a_2)}] \quad (7)$$

The second property suggests that the utility of the risky prospect  $a_j$  is equal to its expected utility, computed as the probability weighted average of the utilities of the individual consequences, while the first property implies that this utility value is equal to the utility of the CE such that:

$$U_{(a_1)} = 0.5U(1000) + 0.5U(0) = U(U_{(a_2)}) = U(450) \quad (8)$$

### 1.6.2. Assessing risky alternatives

According to the subjective expected utility (SEU) hypothesis [12, 42], the decision-makers utility function for outcomes is necessary in order to assess risky prospects. The SEU hypothesis states that the utility or index of relative preference, of a risky prospect is the decision-makers expected utility for that prospect, that is, the weighted average of the utilities of outcomes. The index is calculated using the decision-makers utility function to encode preferences for outcomes. Given a choice among alternative risky prospects, the hypothesis implies the prospect with the highest expected utility which is preferred.

The expected utility of any risky prospect can be converted through the inverse utility function into a CE. Ordering prospects by CE is the same as ordering them by expected utility, that is, in the order preferred by the decision-maker. Besides, the difference between the CE and the

expected value of a risky prospect, referred to as the risk premium (RP), is a measure of the cost of the risk:

$$RP = E - CE \quad (9)$$

In the case of a risk-averse decision makers, RP will be positive and its magnitude will depend on the distribution of outcomes as well as the decision makers attitude to risk.

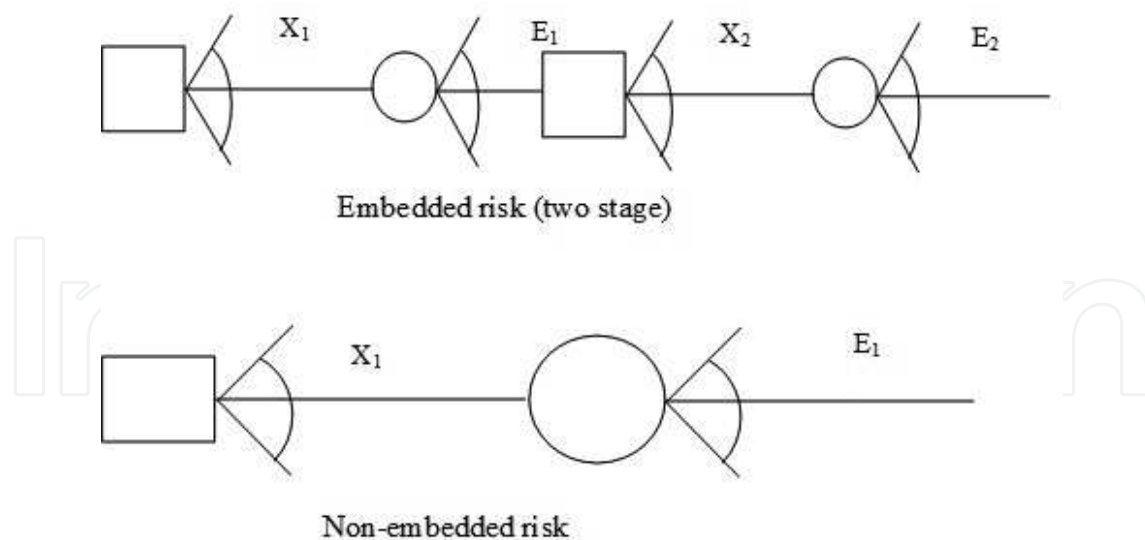
As shown, thus SEU hypothesis demonstrates how to integrate the two components of utility (preference) and probability (degree of belief) to afford a means of ranking risky prospects, thus enabling risky choices to be rationalized. The utility a person gains from a decision and not just the expected financial return obtained from it are as important in making risk management decision.

A study by Kingwell [43] using a model called Model of Uncertain Dryland Agricultural System (MUDAS) looked at the effect of risk attitudes on responses to risk in dryland farming systems. Under the two price scenarios considered, increased risk aversion shifted resources away from cropping toward the livestock enterprise and changed the tactical management of the farming system. In particular, increased risk aversion reduced the area of crop in favorable weather-years and enabled pasture to be produced, thereby supporting more sheep at higher stocking rates. A study by Kingwell et al. [32] explored the importance of considering tactical response in addition to the traditional risk attitude in modeling agricultural systems. They concluded that stochastic models which do not include activities for tactical adjustments miss the benefits of flexibility due to knowledge about uncertain prices and costs (read profit). Inclusion of tactical response options has previously received little attention compared to farmers' risk attitude [44].

The benefits of including tactical response options in a farm model are often greater than the benefits of including risk aversion were hypothesized by Pannell et al. [33]. The importance for strategic choice of accounting for the opportunities to tactically respond to outcomes of risk provided by each strategy has attracted attention [43]. Regardless of whether farmers are averse to risk, prefer it or are ambivalent about it, they tactically adjust their farming strategies as the outcomes of risk relating to seasonal conditions, prices and other sources of risk become known [45]. This is what constitutes embedded risk [35].

### 1.7. Embedded risk

Evaluation of farmers' risk attitude mostly addresses non-embedded risk where activities are assumed to have known resource requirements but to yield uncertain returns, as a result of physical yield or output price uncertainty [46]. In many situations, however, farmers face "embedded risk" [35], where they have the opportunity to make sequential decisions and adjust the timing and methods of their activities as a season progresses and more information on uncertain events or occurrences becomes available. Embedded risk allows for adjustments to be made to farming operations tactically to suit the conditions as they develop, that is, to make management changes within a season. **Figure 2** below was obtained from Ref. [35] to simply illustrate a decision tree notion of options or choices within a season.



**Figure 2.** Embedded and non-embedded risk decision tree [35].

An argument was made by Hardaker et al. [35] that modeling farming system considering non-embedded risk is inadequate since it assumes that it is realistic to model a system as if all decisions (e.g.,  $X_1$ ) are made initially and then the uncertainty unfolds subsequently in terms of risky consequences (e.g.,  $E_1$ ) of the choice taken. In an embedded risk scenario, decisions are segregated into those taken initially (e.g.,  $X_1$ ) and those taken at a later stage (e.g.,  $X_2$ ) when some information on uncertain events (e.g.,  $E_1$ ) has unfolded. Most real decisions about farming systems have the characteristics of the second case where farmers respond tactically as information on uncertain events becomes available. Despite this reality, many mathematical programming models (MP) addressing decision-making in agricultural systems have either ignored risk or have treated it as non-embedded [35] pointed to the complexity of modeling embedded risk as the main cause of this omission. The importance of embedded risk is to complex, diverse, and risk prone agriculture was examined by Dorward and Parton [47]. They discussed risk such as uncertain climatic behavior, pests and diseases as well as output price risk in agriculture. They then described how a farmer could respond to the uncertainty as the season progressed and more information became available as shown in **Figure 3**.

The work by Pannell et al. [33] hypothesized that the benefits of including tactical response options in a farm model are often greater than the benefits of including risk aversion. This is in line with studies by Kingwell et al. [32] and Marshall et al. [44], Kingwell et al. [32] found that modeling tactical adjustments resulted in the identification of an optimal farming strategy expected to be 20.0% more profitable on average than the strategy that would have been identified considering a non-tactical approach. Modeling risk aversion was found to result in the identification of an optimal strategy that had only 2.0–6.0% higher CE than the strategy that could otherwise have been identified [43]. The study by Marshall et al. [44] in supporting the hypothesis by Pannell et al. [33] noted that, failing to account for risk aversion would not affect the strategy chosen; however, failing to account for tactical adjustments would lead to the choice of a sub-optimal strategy. Their research investigated the optimal reticulation strategy in relation to the storage of irrigation water. Alternative strategies were modeled assuming

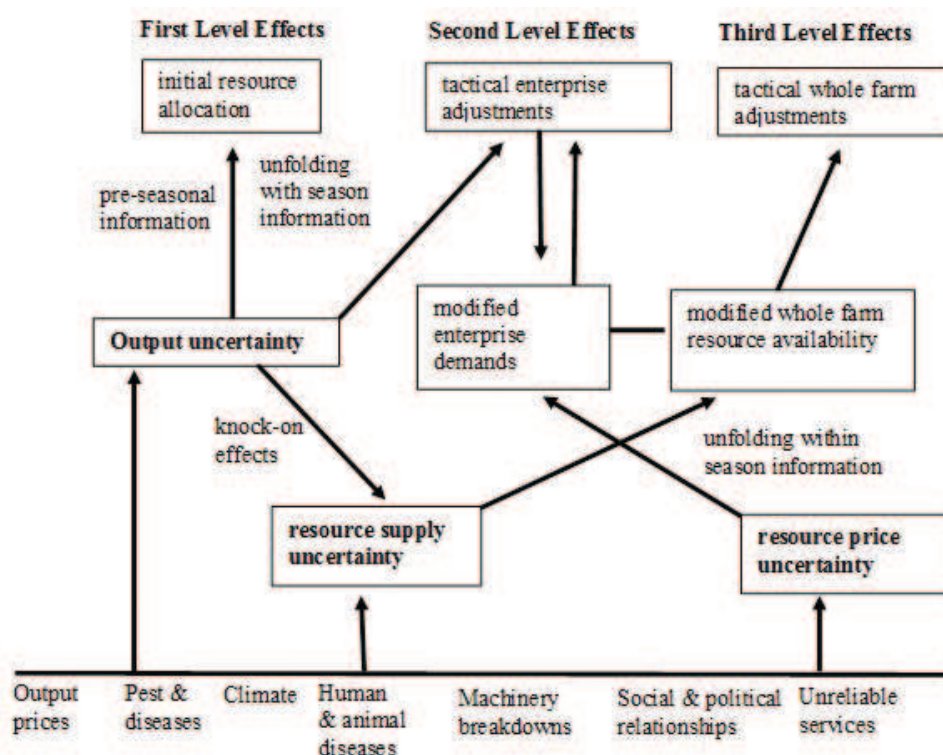


Figure 3. Tactical responses to uncertainty [47].

farmers to be either risk-neutral or averse (within bounds). The strategy determined to be optimal under the assumptions above was then compared against the optimal solution when the model allowed for tactical adjustments. They showed that failing to account for tactical responses would lead to the choice of a sub-optimal strategy, costing the farmer about \$3,100 Australian dollars in present value terms. In contrast, failing to account for risk aversion would not affect the strategy chosen. This confirms the observation made by Hardaker et al. [35] that there are potential dangers in ignoring the benefits and costs of tactical choices allowed by the strategies being evaluated. To confirm the importance of including tactical response options in farm models [46] emphasized the need to undertake further studies. The research from this chapter findings was extracted contributed to the critically needed information on the importance of including tactical response options in farm models.

The findings by Antle [45] demonstrated that seasonal variation affects both risk-averse and risk-neutral farmers' decision-making. Risk-averse farmers adopt long-term farming strategies which show preference for lower but stable income. The study by Kingwell et al. [32] established that most farmers are risk-averse. Both risk-averse and risk-neutral farmers make tactical adjustments to their farming strategies in response to short-term seasonal conditions. There are potentially two facets to the value of climatic information used to make these adjustments. Firstly, they allow for improvement in expected income for all farmers, and secondly, they can reduce the cost of risk for farmers who are risk-averse [32].

Agricultural economists have invested more resources in studies of the longer-term implications of seasonal variation for risk-averse farmers with much less emphasis going into short-term



(within season) tactical decisions [32]. The work by Mjelde et al. [48] demonstrated that even where models allow for seasonal variation and risk-aversion, the common practice has been to ignore the potential for tactical adjustments to the farming strategy according to short-term conditions. The result is an underestimation of the profitability of some strategies [34] and inconsistent production function parameter estimates [45].

## **2. Risk sources and management strategies in dryland pastoral systems in New Zealand**

The researches by Martin [49, 50] identified a range of risk sources and corresponding management strategies in a wide variety of farming systems in New Zealand, including both irrigated and dryland pastoral production systems. Results from Ref. [49] survey-based study of pastoral farmers ranked change in products prices as being the most important risk source. Changes in world economic and political situations, changes in New Zealand economic situation, changes in input costs, rainfall variability, pests and diseases (for deer farmers), changes in producer board policies (for dairy and deer farmers), changes in government laws and policies (for deer farmers) and risks associated with accidents or health problems were the other risk sources identified by farmers in the pastoral sector as being important. A previous survey-based study involving dryland sheep farmers on the Canterbury Plains by Boggess et al. [53] identified the three most important risk sources as rainfall, livestock/product prices, and the world economic and political situation.

All the three groups of pastoral farmers surveyed by Martin [49] noted that routine spraying and drenching and maintaining feed reserves were the most important risk management responses. Low debt level was considered important in risk management as was managing capital spending and maintaining short and long-term flexibility in farming operations. Additionally, sheep, beef cattle and deer farmers utilized market information, spreading sales and investing in more than one enterprise as important risk management strategies. The work by Harris et al. [51] singled out use of animal feed reserve to be the most important risk management strategy, followed by production flexibility, market information and pacing of investments and expansion.

It is Gray et al. [52], who classified risk management strategies into three broad categories; those targeted to feed supply, feed demand and marketing decisions. They went further to suggest farmers need to design their systems to cope with these production and market risks. In coping with production risk, farmers have to increase feed supply over the summer and autumn, and target to transfer feed from the spring to the summer-autumn and winter periods, significantly reduce feed demand over the summer-autumn period, protect capital stock live weights and ensure adequate pasture cover levels at lambing.

To eradicate and/or reduce the negative impact of market risk [52], suggested that farmers should: aim for the sale of stock in periods when most other farmers are not selling, target to finish the bulk of stock rather than sell stores, target to purchase stock at times when other farmers are not buying, and generate adequate feed reserves that can be used to delay stock

sales in drought until such a time as the markets improves. They identified four main tactical adjustments to cope with variation in feed supply within years. These were a need for a sophisticated monitoring system that quickly identifies problems or opportunities, a plan with clear targets that monitored data can be compared against, a historical database of climatic and farm performance data, and a broad set of contingency plans and associated decision rules to determine the best option to implement for the existing conditions.

Other risk management strategies have been suggested by different authors such as geographical dispersion by Boggess et al. [53] where farmers buy land in areas where summer production circumstances are good. This strategy would be expected to reduce market risk but it may come with increased financial risk [52]. The study by Finlayson et al. [4] identified destocking as the most used strategy in drought with farmers preferring to dispose of stock instead of incurring the cost of supplementing animals or grazing them off. Other options used in response to dry conditions have been summarized by MAFPolicy [54] as rotational grazing, maintenance of buffer stock, wintering dry ewes and reducing replacement numbers to match feed supply.

Research by Bywater et al. [55] identified the possibility of rainfall decreasing during late spring and early summer to a point where grass growth ceases as a major source of risk in dryland pasture systems and suggested that important variables in managing this risk are fast lamb growth rate and the flexibility to change feed demand (by destocking) or feed supply (by feeding supplements) rapidly when conditions dry out. Lamb growth rate is important because the risk of dry conditions and reduced feed supply increases as the season progresses and faster growing lambs have a higher chance of being drafted before conditions change.

A key variable in lamb growth rate is feed quality. Use of alternative pasture species has been identified as having potential to improve the profitability of hill country farms by Korte and Rhodes [17] so long as the improved pasture production and quality can be captured by livestock in a profitable way. The study by Fraser et al. [56] also investigated improved pasture species under dryland conditions and showed an increase in lamb growth rate and rate of drafting compared with conventional pastures but noted a lower persistence of the improved pasture species. Other studies that placed emphasis on high-quality feed particularly during the pre-weaning period were those by Kinnell [57] and Gray et al. [52]. However, unlike the research from which the information presented in this chapter was obtained from they did not consider use of alternative pasture species to achieve high-quality pasture during lactation. The research by Grigg et al. [58] showed that managing subterranean clover to maximize yields increased subterranean clover content to 40–60% of sward dry matter content over spring. This resulted in increased lamb growth rates from 258 to 350 g head<sup>-1</sup> day<sup>-1</sup>, lamb weaning weights from 29.6 to 40.0 kg and lambing percentage from 108 to 140% through improved ewe weaning weights. The benefits were as a result of more than 7 years use of a range of strategies including application of fertilizer and lime, property sub-division and subsequent improvement, building up a subterranean clover seed bank, controlled grazing of seedlings in autumn, spelling for 2 months pre-set stocking, and managing spring seed head development.

Research by Avery et al. [59] proposed use of lucerne in dryland systems allowing farmers to grow and finish stock faster over late spring, summer and autumn compared to traditional

pastures. The advantage they noted was that lucerne produced higher quality feed as well as a greater quantity over drier months and is more persistent in dryland environments. By extension the downside in use of alternative pasture is the limited feed supply (reduced production) over winter which [59] addressed through the use of Omaka forage barley and annual ryegrass. Financial benefits of the change from a conventional feed supply system reported by these authors have been dramatic.

The field trial carried out by Bywater et al. [60] to investigate and demonstrate key aspects of high performance sheep systems in dryland environments had an emphasis on high pasture quality and utilization, use of breeding ewes selected for low bodyweight and high fecundity (high efficiency ewes [61], and inclusion of flexible management strategies to allow rapid destocking as soon as conditions became dry. The trial considered most of the risk management strategies and flexibilities discussed above.

The information contained in this chapter extended the trial of Bywater et al. [60] to further evaluate risk management strategies and flexibilities by varying stocking rate, pasture combinations, flexibility options and soil moisture levels used to initiate destocking/sale response. Risk management strategies considered include:

- Early lambing of older ewes to allow early weaning and sale
- Use of 2-yr-old cattle to assist in maintaining low residuals in sheep pastures and as a readily sellable stock class
- '2 yr' ewes instead of cattle with majority lambed early
- A paddock of lucerne in grass dominated systems to extend feed supply in dry conditions
- All stock sold before the end of the year
- Use of supplements and grains when absolutely necessary

## **2.1. Integrating a framework for implementation of tactical decisions in grazing systems models**

As noted previously this chapter was extracted from a research that was carried out in dryland farming system and therefore constituted a good case study to demonstrate the efficiency of integrating tactical responses in agricultural systems. Dry land farming on the east coast of New Zealand is subject to significant climatic variability. In the location of this study on the Canterbury plains, winters are normally cool and wet and summers warm and dry, although not always so. Spring and autumn can either be wet or dry, warm or cool. The typical pattern of pasture growth is one of very low growth during winter because soil temperatures are too low even though there may be sufficient moisture, accelerating growth from mid August as soil temperatures start to increase, reaching a peak around October/November followed by an abrupt drop in growth as soils dry out because of a lack of rainfall in summer (anytime from October onwards), a resurgence of growth with the autumn rains in April/May and a return to low growth again as temperatures drop from June onwards. However, spring growth may be delayed because of cooler or dryer conditions than are typical; spring/summer growth may

cease early if there is little rainfall after September or it may continue throughout the season if there is a wet summer; there may or may not be autumn rain. Dryer, cooler conditions early in the season (September/October) may be followed by wetter, milder conditions later (November/December) so that growth patterns can be almost reversed. There have been some years, such as the 1988–1989 drought when there was no rain for 18 months.

From a pastoral livestock perspective, there is generally adequate grass growth in most years to support production from August through to anytime after October when soils dry out and grass growth stops. This provides a 3–5 month ‘window of opportunity’ for production and most farmers aim to lamb in August/September and have the majority of their lambs finished before Christmas. There is the very strong possibility that lambs remaining on the farm after December will not grow well because of inadequate feed quantity or quality, and with typically falling prices from November onwards, it is often better to sell lambs as store stock early than keep them in the hope of finishing them for the works, only to be forced to sell them as stores later.

From a production and profitability perspective then, perhaps the most difficult period of uncertainty and risk is the time at which conditions dry out in spring/summer and grass growth ceases. Most commentators note that farmers generally wait too long to respond to drying conditions in the hope that there will be some rain, grass growth will recover, and they will be able to put more weight on their lambs before sale. The second most difficult period is autumn in terms of providing adequate feed quantity and quality to flush ewes to ensure high lambing percentages in the following season. This can be exacerbated if lambs are retained, grow slowly over summer, are held too long and start to compete with ewes for the best available feed during flushing.

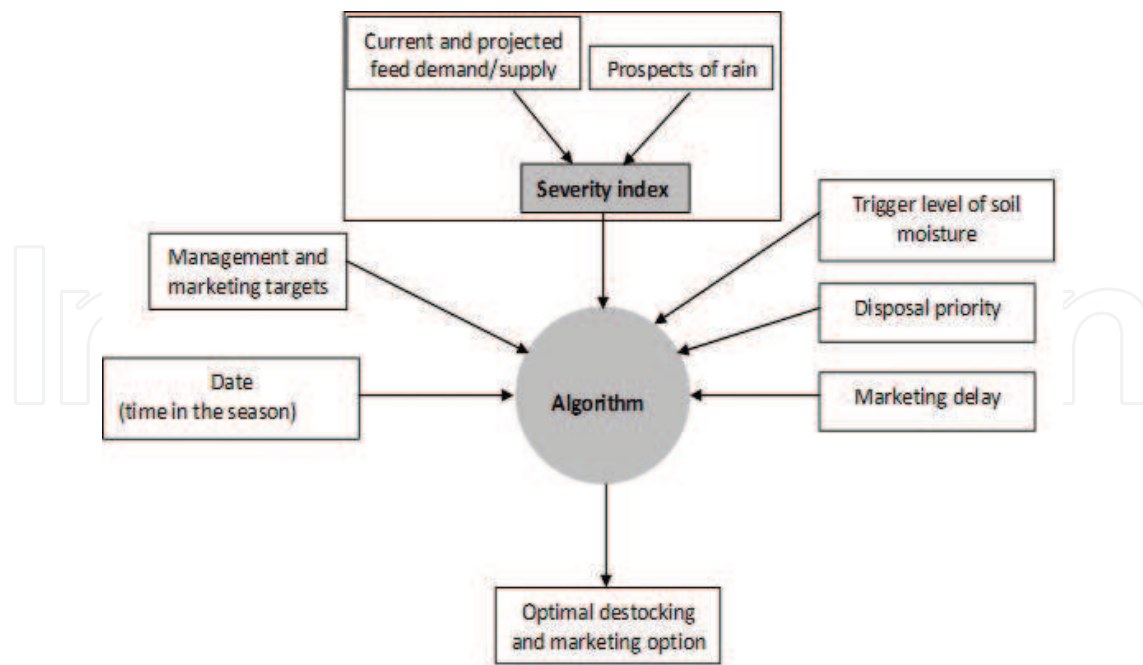
Decisions on the stock type and number of animals of each type to retain on the farm introduce a complexity in managing the grazing system to achieve optimal productivity and profitability due to this seasonality and annual variability of forage production. Timely decision-making and subsequent actions are crucial to the survival and profitable running of high-performance dryland grazing sheep systems in these climatic conditions.

In order to evaluate different tactical responses to climatic conditions in this situation, an algorithm was developed to carry out destocking and marketing decisions where productivity and profitability are highly influenced by climatic variability. The algorithm is designed to be actioned when soil moisture level reaches a predetermined trigger value indicating the (temporary) cessation of pasture growth and to respond to an assessment of current feed availability on the farm and the prospect of rainfall which will stimulate utilizable pasture growth in time to feed the animals on hand.

## **2.2. Design, development and implementation of the destocking algorithm**

A generic destocking and marketing algorithm were designed and implemented to assist in making tactical destocking and marketing decisions. The aim was to evaluate the effects on productivity and profitability of alternative management responses to different scenarios with respect to feed availability and current and prospective climate conditions, and different trigger values defined as different levels of soil moisture.





**Figure 4.** The destocking and marketing algorithm.

**Figure 4** shows diagrammatic representation of the algorithm. Based on the time of the season, the target trigger level for soil moisture, current and projected feed demand/supply, prospects of rain, severity index and producer defined stock disposal priority, the algorithm calculates the optimal destocking and marketing option. Tests run from left to right of the diagram. The algorithm loops back to the beginning (time in the season) whenever a condition is not met (e.g., a value below the desired date when destocking and/or marketing action(s) should be activated). The algorithm repeats the process after a defined period (e.g., 7 days from the last test date).

The illustration below shows the pseudo code implementation of the destocking algorithm.

### Definitions:

$T_i$ : series of decision times

$M_i$ : soil moisture at time  $T_i$

TM: targetmoisture

TM<sub>Levels 1-3</sub> are 10, 12.5 and 15% of the top 25 cm soil respectively

$S_{ji}$ : stock class  $j$  on the farm at time  $T_i$

where  $j = 1, \dots, 5$  represents capital ewe, lambs, cull ewes, 1st cycle ewes, and cattle stock classes respectively

$N_{ji}$ : number of animals in stock class  $j$  at time  $T_i$

$F_i$ : farm feed supply at time  $T_i$

$R_{ji}$ : corresponding stock class feed requirement at time  $T_i$

$D_{ji}$ : total animal feed demand at time  $T_i$



$$D_{ji} = \sum_{j=1}^5 R_{ji} \times N_{ji}$$

$PR_i$ : the probability of substantial rain falling at time  $T_i$

where  $PR_i$  is one of high, medium or low defined as follows:

High: High chance that a rain event occurs and that the amount is enough to cause pasture growth that can sustain animals on a farm

Medium: Moderate chance that a rain event occurs and that the amount is enough to cause pasture growth that can sustain animals on hand

Low: Low chance that a rain event occurs and that the amount is enough to cause pasture growth that can sustain animals on hand

$SI_i$ : severity index at time  $T_i$

where  $SI_i$  is one of high, medium or low defined as follows:

High: feed days available limited and chance of substantial rain falling low

Medium: feed days available limited and chance of substantial rain falling moderate

Or

feed days available unlimited and chance of substantial rain falling low

Low: feed days available unlimited and chance of substantial rain falling high

$P_{ki}$ : stock class corresponding to feeding priority  $k$  at time  $T_i$

where  $k = P_{k1-5}$  is  $S_{j1}, S_{j2}, S_{j3}, S_{j4}$  and  $S_{j5}$  and  $S_{j1}, S_{j2}, S_{j3}, S_{j4}$  and  $S_{j5}$  for pre- and post weaning respectively

$A_{di}$ : destocking action  $d$  at time  $T_i$

where  $d = 1, \dots, 3$  represents destock heavily, low to moderate destocking and do not destock now respectively

### Algorithm

Function destock()

For times  $T_i, = 0, \dots$ , end in steps of 7 days

If soil moisture ( $M_i$ ) < target ( $TM_i$ ) then

Calculate  $F_i$

Calculate  $D_{ji}$  for each stock class  $j$  from  $T_i$  to  $T_{i+1}$

Calculate total animal feed demand ( $\sum D_{ji}$ )

```

Evaluate feed situation (compare total animal feed demand with  $F_i$ )
Get the probability of substantial rain falling ( $PR_i$ )
Calculate the severity index ( $SI_i$ )
If  $SI_i$  is equal to high then
    Destock heavily ( $A_{d1}$ )
Else if  $SI_i$  is equal to medium then
    Apply low to moderate destocking ( $A_{d2}$ )
Else if  $SI_i$  is equal to low then
    Do not destock now ( $A_{d3}$ )
Else do nothing
Return output

```

### 2.2.1. The destocking algorithm

Running the destocking and marketing algorithm under four potential feed scenarios on a given farm resulted in **Figure 5**. **Figure 5A** represents a scenario where feed available is more than enough to feed all stock types on the farm, **Figure 5B** shows a feed situation where the farmer can feed the capital stock sufficiently and remain with some feed which can be utilized by a proportion of non-capital stock. Under the scenario depicted by **Figure 5C**, the producer would only be able to retain the capital stock on the farm as the feed available is just enough to meet the requirements of those stock. The situation represented by **Figure 5D** means the farmer has either to buy supplementary feed for the breeding stock (capital stock) if a decision is made to retain part or all of the capital stock on the farm, sell a certain proportion of the stock or acceptably underfeed the capital stock. There is also a possibility of combining any two or more of the response noted above to reduce capital stock feed demand on the farm.

Scenarios A, C and D are easier to deal with than scenario B. For instance, in case A, non-capital stock would be sold according to the desired target drafting weight and any extra feed could be sold or conserved for future use. Feed circumstances described by scenario C dictates that the producer can only feed the capital stock and so any other stock on the farm has to be disposed if the cost of buying feed to maintain them is greater than the benefits (i.e., loss avoidance). Under scenario D, feed has to be bought into the farm to feed the capital stock. The other alternative would be to sell a part of the capital stock to release feed required to take the remaining number of animals on the farm to the end of the season.

The feed profile for scenario B can be considered to fall between scenarios A and C, allowing it to be defined within maximum and minimum constraints. **Figure 6** shows the minimum (requirements for capital stock) and maximum (reference profile) constraints. The area between the two constraints represents the feed needed to supply nutrients required for non-capital stock to the end of the season. The minimum constraint is more important since it is the

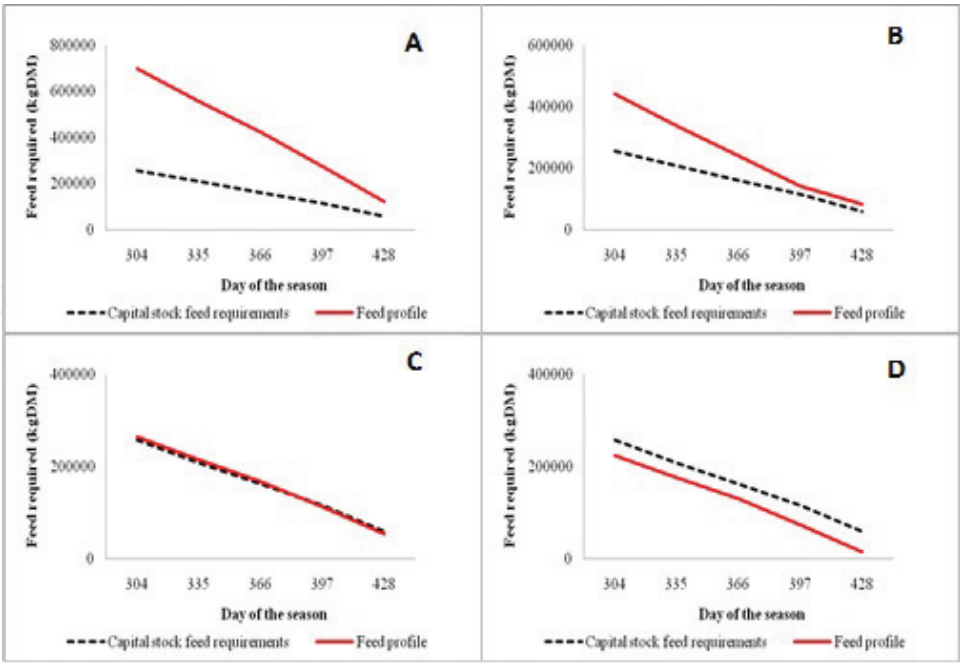


Figure 5. The four potential animal feed demand and supply scenarios (A–D) under a grazing system.

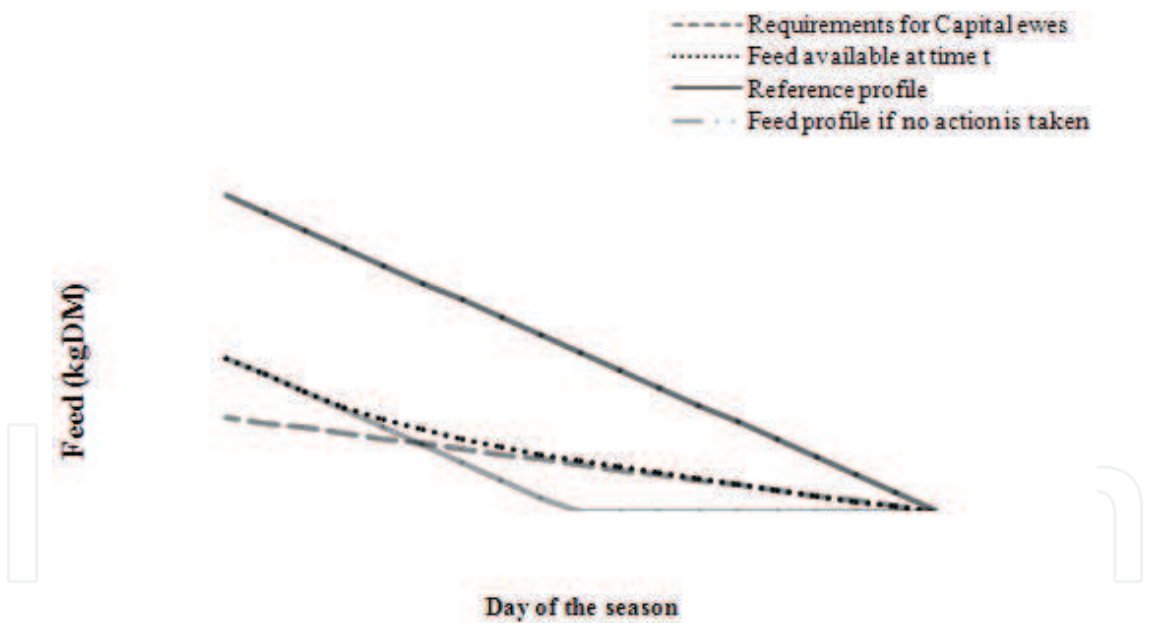


Figure 6. Results from the destocking and marketing algorithm feed profiles.

minimum feed required to supply the capital stock to ensure acceptable levels of (re)production in the following season.

The curves presented in **Figure 6** were obtained from implementing the destocking and marketing algorithm. There are two options available to a farmer faced with feed scarcity as shown in **Figure 6**. At any given point in time when conditions dry out, depending on the current feed demand and supply and the prospects of receiving sufficient rainfall to generate

enough pasture growth to supply the anticipated feed deficit, the farmer could retain the stock on hand and follow a predetermined marketing policy to the end of the season or until conditions dry out again. However, if there is little prospect of rain falling and the feed available cannot carry the stock on hand to the end of the season, the producer may opt to destock to match the feed demand and supply. For the example presented here, the farmer would only be able to retain stock on hand for 61 days (between day 304 and 365) if no action is taken to destock the farm and there is no rain. If on the other hand the farmer's decision is to destock the farm, the algorithm should ensure that the feed available is utilized optimally, that is, no feed remains on the farm at the end of the season following destocking. Optimal solutions should map the feed profile curve as close to the minimum constraint as possible following destocking. The current algorithm was able to satisfy this requirement as no feed remained on the farm at the end of the season (the February 28; in the context of this study) as shown in **Figure 6** (feed available at time  $t$ ).

### 2.2.2. The 'severity index'

The combined effect of current feed demand and supply and the probability of sufficient rain falling to stimulate pasture growth were incorporated in the algorithm by developing a severity index (SI) as a guide to how aggressive the farmer should be in responding to any given situation.

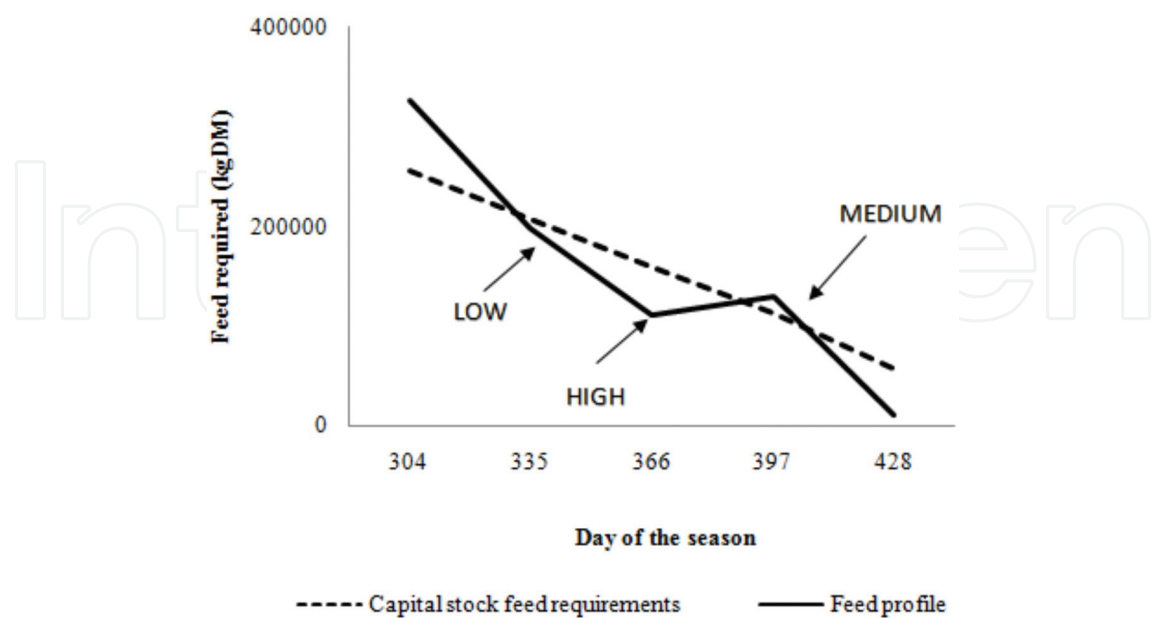
Soil moisture level is a balance between the addition of water (through rainfall or irrigation) and loss through evapotranspiration. If there is no rain falling or irrigation being applied to replace the lost water, the soil moisture falls to the extent that plants reduce growth and ultimately wilt and die [53]. A survey presented by MAFPolicy [54] indicates that at least 65.0% of farmers take current crop condition and forecasted weather into consideration with respect to the state of the soil moisture on their farms for the purposes of feed planning. The survey concluded that the majority of farmers considered the state of the soil and the crops, and how the two might change given the weather forecast in their management decision-making. This approach was used to develop the SI. In addition to the soil and pasture conditions and weather forecast, a feed budget to the end of the season is calculated. This ensures that the index is not just responsive to the current feed situation but rather to the combined effect of the current and prospective feed supply/demand situation and the possibility of receiving rainfall.

The algorithm is designed to scan rainfall forecasts for a user defined number of days ahead of the test day. With the rain forecast obtained, an approximation of the quantity of additional feed resulting from the rainfall is made. An analysis is then done to determine whether the feed at hand is enough to carry the animals at hand to a time when the projected feed resulting from the rainfall event(s) is available, and this modifies the SI. It is important to note, however, that the prospect of rainfall does not change the amount of feed available at the test day, rather it results in an approximation of feed available at and after the time the rainfall event(s) occurs. Weather forecast data are readily available in New Zealand from the National Institute of Water and Atmospheric Research Ltd of New Zealand (NIWA). Where the algorithm is used as a standalone decision aid, forecasts of the prospect of receiving rainfall in a future period are assumed to be obtained from NIWA. In the context of the simulation, a 28 days rainfall forecast

was utilized, but due to the fact that the study was based on historical weather data for the 19 years of analysis, it was assumed that rainfall records for 28 days after the test day were indicative of such a forecast. The ‘forecast’ was thus read from climate data input files. Note that the severity index has no bearing on the calculation of current feed demand or supply, it simply alters the aggressiveness or otherwise of the response to the current feed situation.

Three levels of severity are defined in the index as low, medium or high. For independent use by farmers, a severity ranking can be assigned by the user according to their production circumstances and experience. But generally, if the farm feed situation and/or the prospect of rain falling is good, severity is considered low. The reverse holds for high severity. Given an evaluation of the severity, the algorithm responds differently in terms of destocking. For instance, if the severity is low, even if the feed available cannot carry the stock on hand to the end of the season, animal disposal can be delayed which may result in feed available falling below the minimum constraint trajectory.

**Figure 7** shows a feed profile curve resulting from a sequential evaluation of the algorithm behavior in the light of encountering the three potential levels of severity. The assumption is that in areas with high climatic variability, it would be possible to experience two or three SI circumstances within a season. The shape of the resultant curve shows that the algorithm is able to respond dynamically to varying severity index levels within a season. At the point marked high on the curve, the algorithm ranks the pasture availability and rainfall probability situation as highly severe, resulting in a heavy destocking (sharp rise noted on the feed profile curve at the decision point) to correct the situation. Under a situation of medium severity, it would be expected that only a certain proportion of the non-capital stock would be retained on the farm since the index is assigned relative to feed demand and supply. This means that the anticipated rainfall and/or current feed situation would still be limiting but to a lesser degree



**Figure 7.** Feed profile for a farm situation where the three severity circumstances are encountered as indicated on the graph.



compared to the high severity scenario. Under low severity, it would be possible to retain all non-capital stock and follow the target marketing strategy, assuming the low severity status is maintained through the season.

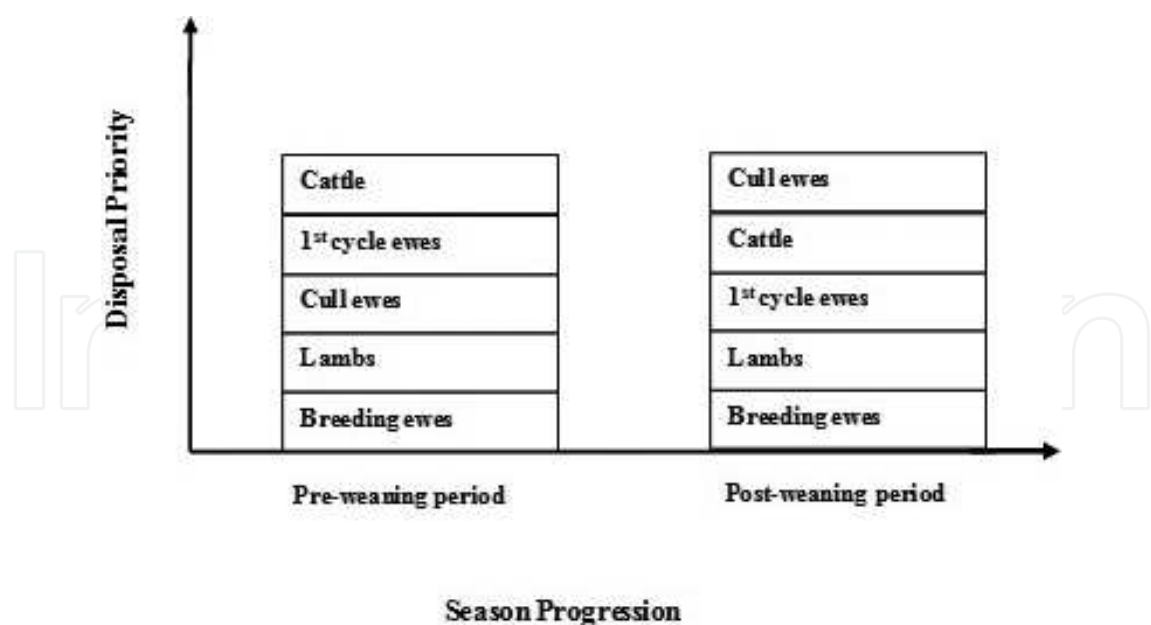
### 2.2.3. *Testing the destocking and marketing algorithm*

A hypothetical farm was defined and different feed scenarios tested using the destocking and marketing algorithm. The farm's overall objective was to maximize productivity and profitability through finishing as many lambs as possible. The farm had a total of 1099 ewes divided into a main ewe mob and a first cycle ewe mob tupped to lamb 3 weeks earlier. The total number of ewes in the first cycle ewe mob (older ewes) was set at 241 or approximately 22.0% of the entire ewe flock. It was also assumed that culling occurred at 16.0% of the total ewes on the farm which totals to approximately 176 ewes. The first cycle ewes were either selected from the cull ewes considered to be in good condition or sourced from outside the farm through purchase. The combined lambing percentage for both ewe mobs was taken to be 155.0% which translates to approximately 1700 finishing lamb assuming no lambs losses occur pre- or post-parturition. In addition to the sheep flock, a total of 120 head of cattle were bought onto the farm in autumn (during May). The cattle and old ewes were considered to provide flexibility options for risk management and could be sold off at any time depending on the feed situation on the farm.

The key options available to a farmer for balancing feed supply and demand in a grazing system in the face of climatic variability partly relate to animal categories on the farm and the economic efficiency of retaining a particular stock type for a longer period on the farm. The first consideration is normally to supply the capital stock (breeding ewes) with sufficient feed to maintain acceptable levels of future (re)production performances before considering retaining any other stock type. **Figure 8** shows stock-type retention priorities for the hypothetical farm as the season progresses.

These stock disposal priorities are based on the policies adopted by the Silverwood farmer reference group for operation of the Silverwood innovative sheep systems trial [51]. Further details of the philosophies and operating policies for the farm units included in this trial are presented in Ref. [55].

It was considered more economically efficient to keep un-weaned cull ewes and their lambs for longer than growing cattle when faced with a feed deficit prior to weaning as shown in **Figure 8** due to the benefits obtained through higher growth rates from suckling lambs. However, once the main mob is weaned, it is more profitable to sell off the cull ewes compared to selling the growing cattle which have the potential to continue gaining weight. In a scenario where cull ewes have been sold and a producer faces a feed deficit and the only potential stock types available for disposal includes growing cattle and lambs, it would be more economically efficient to sell the growing cattle. In extreme cases, such as is in a developing drought situation, the producer's choices are limited after sale of all disposable stock types (that is—cull ewes, cattle and lambs) and the only options would be to (i) buy feed to supplement breeding stock (capital stock) if a decision is made to retain all or part of the capital stock on the farm, (ii) sell all or part of the stock or (iii) acceptably underfeed the capital stock which can be also considered as the wait and see strategy (A.C. Bywater, pers com).



**Figure 8.** Stock-type disposal priority for the hypothetical farm with the progression of the season.

**Table 2** shows sample potential decision rules for the hypothetical farm based on different feed and moisture level circumstances. The table is divided into four sections. Items in the top two sections represent a list of conditions to be tested and the respective condition values. Items in the bottom two sections show the list of potential actions and the actions taken in response to results from the tested conditions. The sample lists a total of 17 distinct decision rules each represented by a column. Each decision rule (column) is a unique combination of a set of conditions-value(s) and the action(s) to be taken correspondingly. For instance, the first decision rule tests whether tailing has occurred. If tailing has not been carried out, the algorithm loops back to test tailing after a period of 1 week. However, if tailing has occurred, it proceeds to test whether the current date is less than 31st October. If current date is less than 31st October, a soil moisture test is carried out and compared to target trigger values of 10.0, 12.5 and 15.0% by volume in the top 25 cm of soil. A value below any of the target trigger values causes the algorithm to do a feed profiling analysis giving dates when destocking should be done to make it to the end of the season. A moisture level above the target trigger values causes the algorithm to divert from the feed profiling analysis to a test aimed at establishing the proportion of lambs whose weight is greater than the target drafting weight (DW) for drafting.

In scenarios where moisture level is above the corresponding target trigger levels of 10.0, 12.5 and 15.0%, tests for feed available for animals on hand are not implemented; rather the proportion of the lambs weighing greater than target weaning weight (WW) and the average lamb LW (ALW) are tested irrespective of the results of the current date test. If more than 10.0% of lambs are heavier than the target DW and the ALW is lower than the target WW, lambs are drafted. Where less than 10.0% of lambs are heavier than the target DW and the ALW of the lamb crop is higher than the target WW, lambs are weaned.

A delay occurs between the time a producer opts to sell stock and the actual killing space allocation. An average of between 7 and 10 days delay has been suggested as the time between

Destocking responses	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Tailing has occurred?	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Current date < 31st October?	-	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
Soil moisture below target level?	-	N	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-
Enough feed for capital stock to a target time in the season?	-	-	Y	Y	N	-	-	-	-	-	-	-	-	-	-	-	-
Enough feed for non-capital stock to a target time in the season?	-	-	Y	N	-	-	-	-	-	-	-	-	-	-	-	-	-
10% of the lambs > Target DW?	-	-	-	-	-	N	Y	N	Y	N	Y	N	Y	-	-	-	-
Lamb avg wt > Target WW?	-	-	-	-	-	N	N	Y	Y	N	N	Y	Y	-	-	-	-
Current date < 15th December?	-	-	-	-	-	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Current date > 15th December?	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	Y	Y	Y
Soil moisture below target level?	-	-	-	-	-	N	N	N	N	Y	Y	Y	Y	-	-	-	-
Enough feed for capital stock to a target time in the season?	-	-	-	-	-	-	-	-	-	Y	Y	N	N	Y	N	Y	N
Enough feed for non capital stock to a target time in the season?	-	-	-	-	-	-	-	-	-	Y	N	-	-	Y	-	Y	-
Current date < 28th February?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-
Buy feed or sell part of the capital stock	-	-	-	-	X	-	-	-	-	-	-	X	X	-	X	-	X
Sell a proportion or all animals in non-capital stock type with no feed allocation	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-
Draft mobs	-	-	-	-	-	-	X	-	X	-	X	-	X	-	-	-	-
Wean mobs	-	-	-	-	-	-	-	X	X	-	-	X	X	-	-	-	-
Wean all mobs	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X
Set draft fortnightly for all mobs	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-
Sell all non-capital stock	-	-	-	-	X	-	-	-	-	-	-	X	X	-	X	X	X
Reset and start again	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

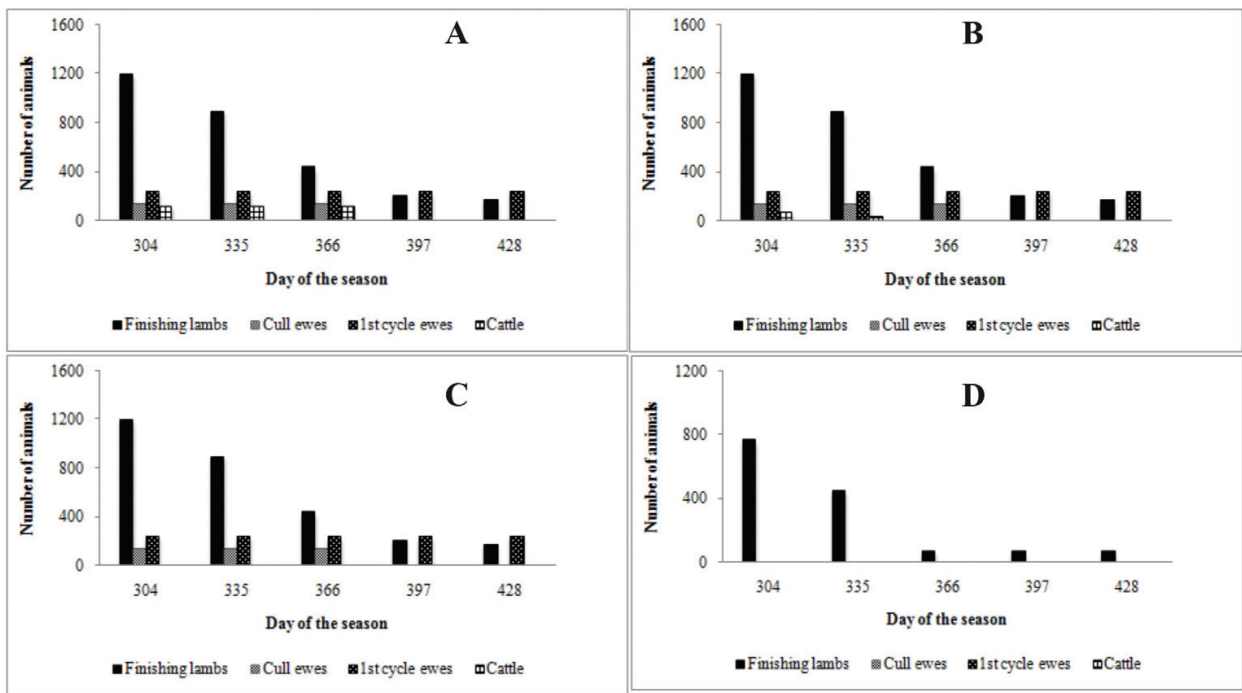
Where N = no, Y = yes, and X the corresponding marketing and/or destocking response.

**Table 2.** Destocking and marketing policies decision rules table for the hypothetical farm.

killing space booking and allocation in late spring through summer for the Canterbury region of New Zealand (A.C. Bywater, pers com). However, the delay is dynamic ranging between 7 and 12 days.

### 3. Results

**Figure 9** presents results for the algorithm test for the hypothetical farm described above. When feed available was enough to feed the non-capital stock to the end of the season, all



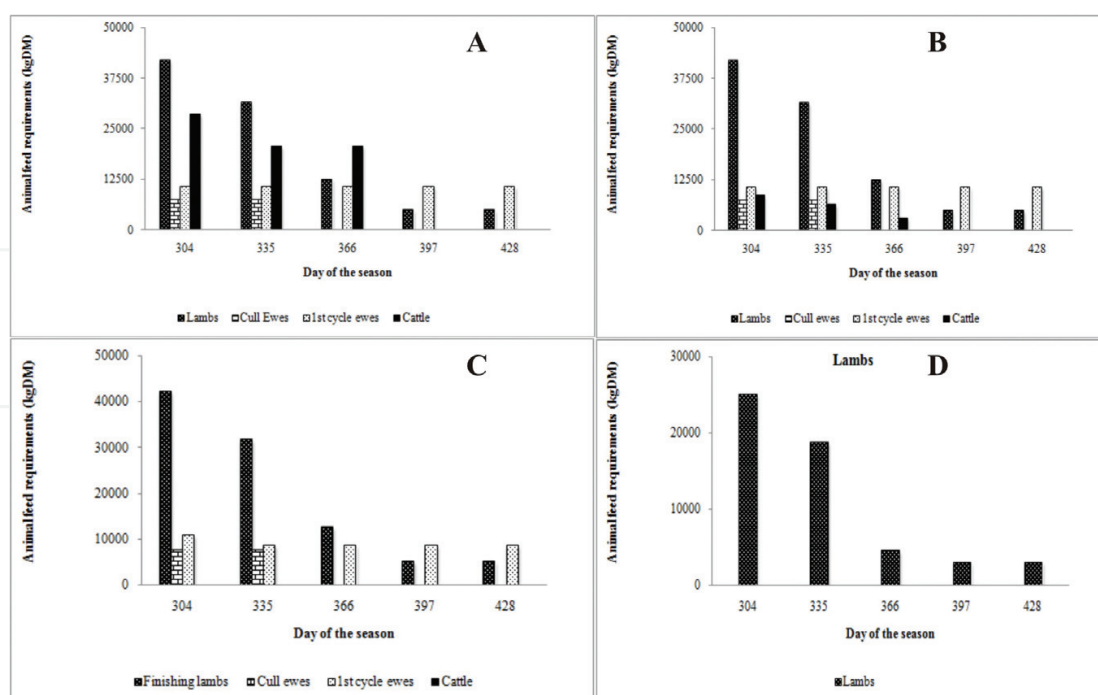
**Figure 9.** Animal number retained on farm when 100% (A), 75% (B), 50% (C), and 25% (D) of required feed is available for the non-capital stock.

stock classes were retained on the farm, and disposal was only as a result of sale following attainment of target drafting weight as shown in **Figure 9A**. This scenario simulates a farm situation where feed available is not limiting which means the destocking and marketing algorithm is able to respond to the planned marketing regime. For instance, all cattle were sold off at the end of the year which was the target marketing policy for the hypothetical farm.

In all cases, cull ewes are sold off the farm after weaning as shown in **Figures 9A–C**, while the 1st cycle ewes were retained on the farm in anticipation of a better than average pasture growth in the following season. In essence, culling could be carried out on the 1st cycle ewe mob with replacements being sourced from cull ewes deemed to be in better (re)production condition than animals in the 1st cycle ewe mob.

**Figure 9D** represents a situation where the farm cannot support all the lambs to finishing. It is notable that the height of the column representing the number of animals is shorter compared to the other three cases (**Figure 9A–C**).

**Figure 10** shows the feed requirements corresponding to the number of animals presented in **Figure 9**. Generally, feed requirements follow the same pattern as the number of animals. The high number of lambs is reflected by high feed requirements especially toward the start of the season but as the season progresses and as more lambs are sold off, their requirements reduce and are overtaken by the cattle and 1st cycle ewes' requirements.



**Figure 10.** Total feed consumed by each stock category retained on farm when 100% (A), 75% (B), 50% (C), and 25% (D) of required feed is available for the non-capital stock.

Unlike lambs and cattle, cull and first cycle ewe mobs were sold ‘all or none’ depending on the feed availability. For example, if a mob had a total of 100 ewes and the feed available is enough to maintain 80 ewes, the mob was sold off entirely. Assuming that lamb feed requirements have been satisfied, such a production circumstance led the algorithm to retain a certain number of cattle that can be fed using the feed saved from selling the entire ewe mob (i.e., feed for the 80 ewes). This algorithm capability ensures that no feed is unutilized irrespective of stock type prioritization.

## 4. Conclusions

Based on the destocking and marketing policies of the hypothetical farm, the algorithm reproduced well the projected and desired results. In general, the algorithm reported here can be used in any grazing system. In order to be used as a stand-alone decision aid, the farmer would be required to provide a stock type prioritization list, an estimate of the feed available at the time, and his or her estimate of the prospects of rainfall, presumably based on official current forecasts (from NIWA in the case of New Zealand). The algorithm has been incorporated into the LincFarm grazing system model [4, 6] model and an evaluation of the extended model carried out for all the new extensions before use in evaluating alternative risk management strategies.



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