Final report

Developing a framework for tactical decision making to address feed deficits

Project code: P.PSH.1027

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Abstract

Making management decisions that involve taking a chance on future climatic conditions is always difficult, especially in variable climates across southern Australia. Producers have highlighted the most difficult period for managing livestock is going into a dry period and they want information about making grazing (sales, feeding) decisions. This project objectively assessed tactical management options and trigger points to provide meaningful information for making flexible stocking decisions. Nine producer consultation workshops were held to identify key management decisions and the thinking behind these decisions. Producer consultations highlighted that producers largely use value-based judgements for decisions and identified the importance of the process and critical dates in decisions. There is a need for strategic preparation in good years (e.g. developing containment feedlots, grain storage or investing in farm management deposits) and a tactical response to year-to-year variability (e.g. incremental adjustments to stocking numbers, calculating the immediate and future impact of decisions and looking for opportunity to grow extra feed when moisture is available).

A modelling framework was developed, and whole-farm economic analysis was used to assess the economic performance of different management decisions. The economic analysis showed that where flexible stocking decisions were used incrementally in response to feed deficits, they reduced the downside risk compared to more rigid systems, but there was a trade off as this often limited overall profitability. The results of the analyses have been compiled into a tool to help producers quantify the risk of decisions, including in recovery years. which is available to improve the profitability of red meat producers in south eastern Australia. This is achieved by increasing certainty of feed supply, better predicting the need for drought feeding at the same time avoiding possible overgrazing and land degradation.

Recommendations are made to validate the findings and benefits of the web tool, being an initial to broader adoption of an approach to informed decision making.

Executive summary

Background

Matching livestock demands with seasonal variation in forage supply is a major challenge for producers. In southern Australian grazing systems, vegetation growth and available feed vary substantially within and between years, whereas livestock numbers and demand are generally more consistent. Several producer surveys conducted in New South Wales indicate matching feed supply to animal demands within a given year was identified as either their first or second top issue without prompting. Furthermore, farmers thought they got grazing decisions wrong about 40% of the time, and these grazing decisions involve tactical management decisions which will be addressed in this project.

Project P.PSH.1027 aims to objectively assess different trigger points and associated strategies for prioritising limited feed. Producers will be able to formulate informed destocking and supplementary feeding policy to improve economic and environmental outcomes. The project has modelled a matrix of farming systems (north to south and east to west) in south-eastern Australia to determine the effectiveness of different strategies. The intended outcome is the development of a web-based learning tool that is accessible to farmers to integrate information.

Objectives

- Tactical management options and trigger points objectively assessed using modelling and whole-farm economics on a matrix of sites from the rangelands to the HRZ of south-eastern Australia.
- A web-based interactive learning tool to objectively assess the type and timing of tactical decisions for use by producers and extension professionals.

Methodology

Challenges and possible decision triggers were identified using nine facilitated producer consultations.

Farming systems and management practices were modelled to adapt to seasonal variability.

Whole-farm simulation modelling which links biophysical data with simulated prices data was used to access the economic performance of different management decisions.

A interactive stocking decision and tactical management tool that will be readily accessible to farmers was developed.

Results/key findings

Producer consultations highlighted that producers largely use value-based judgements for decisions and recognised the importance of the process and critical dates in decision making.

Key themes from the consultation include:

- *strategic preparation in good years* by developing containment feeding lots, developing grain storage or investing in farm management deposits (FMDs); and
- *tactical response to year-to-year variability* by clearly understanding available feed compared to livestock demands, incremental adjustments to stocking rates with sale of the appropriate class of livestock, calculating immediate and future impact of decisions, looking for opportunity to grow extra feed when moisture is available and understand agistment options.

The economic analysis showed that where flexible stocking decisions were used incrementally in response to feed deficits, they reduced the downside risk compared to more rigid systems, but often limited overall profitability.

Benefits to industry

The understanding in this project and the tool combined with a full adoption plan will contribute to an increase in the profitability of the red meat industry in south eastern Australia by increasing certainty of feed supply, better predicting the need for drought feeding at the same time avoiding possible overgrazing and land degradation. The red meat industry will also benefit from human development as producers become more confident in making better tactical management decisions to adapt to seasonal conditions. As a result of better stocking management decisions, animal welfare conditions could be improved by reducing stress caused by overstocking during times of feed deficit.

Future research and recommendations

There is a clear need for an adoption phase to ensure the estimated impact of this project is possible. This will first require a wider validation of the tool with producers and adjustment to their needs. This validation will involve evaluating the tool with individual producers from each of the groups that were part of project, plus additional producers who were not part of the current phase of the project. This will also involve the competition of the approach used with the SGS model for the rangelands to be completed at Broken Hill.

The tool has been developed in an Excel® format, which can be hosted on websites in its current form. The Excel® format was chosen so that the tool can be developed into a web frontend with existing software (e.g. stockplan) for producer to calculate the impact of their own drought scenarios. This redevelopment of drought management software is currently being undertaken by NSW DPI. Having these two components was identified by advisors as being important for the impact of the tool.

Table of Contents

1. Background

Matching livestock demands with seasonal variation in forage supply is a major challenge for producers. In southern Australian grazing systems, vegetation growth and available feed vary substantially within and between years, whereas livestock numbers and demand are generally more consistent. The considerable year-to-year variability in available feed is driven by the variability of climate that predominately influences soil water. Locations with higher year-to-year variability in pasture growth are managed with more conservative stocking rates and lower herbage utilisation to avoid costs associated with supplementary feeding, destocking livestock and re-sowing pastures due to degradation, than those with a more consistent rainfall. However, if reliable trigger points could be defined to adapt management, then utilisation could be increased in a less risky way.

The issue of variability in feed supply has been extensively tested with producers and work on tactical decision to adapt to variability was initially developed during the national EverGraze program. In addition, a three-month intensive program, using lean start up methodology, was used to test how much of a problem seasonal variability is with producers. There were several techniques used, including a producer group consultation (~20 producers), phone interviews with 10 producers and several online surveys. Some of the information generated highlight the extent of the problems producers are facing. Of the phone interviews conducted, matching feed supply to animal demands within a given year was either their first or second top issue identified without prompting. In this same survey farmers highlighted the most difficult period for managing livestock is going into a dry period and they want information about making grazing management/sales/feeding decisions. An on-line survey of 120 producers highlighted that, farmers thought they got grazing decisions, such as supplementary feeding, early weaning or drying off cows, changing the sale time of animals, wrong about 40% of the time, and these decisions involving tactical management are addressed in this project.

Although it is difficult to predict the actual pasture supply within and between years, some tactical decisions have proven useful in the temperate pasture zone. These include altering the amount of N fertiliser applied (for high input dairy systems); early weaning or drying off cows; allocating limited high-quality pasture to high value livestock classes; changing the sale time of animals; higher culling rates; and supplementary feeding. While the most accomplished farmers intuitively make good tactical decisions, there has been little research to determine which decisions ensure the best outcome at different times, especially when variability in price is included.

In addressing this problem for Australia's temperate grasslands, Chapman *et al.* (2013) proposed using forecasting based on current soil moisture to specify the likelihood of forage supply to meet livestock demands. This approach seems to improve prediction of pasture availability at the beginning and end of the main growth periods e.g. November and early March when variability in pasture growth between years is a greater problem to manage. These forecasting approaches have been incorporated in general tools for use by farmers such as the MLA Rainfall to Pasture Growth Outlook Tool, which is no longer operational. As a first step, these tools provide acceptable guides for future pasture growth levels, but more research is needed to consider current feed-on-offer and variations in farm resources to give more certainty that forage prediction will meet current livestock demands. This has been improved with the recent release of the Farming Forecaster software (https://farmingforecaster.com.au/), but this tool currently does not have options to respond to rainfall deficits with tactical management decisions.

Project P.PSH.1027 aims to objectively assess different trigger points and associated strategies for prioritising limited feed. Producers will be able to formulate informed destocking and supplementary feeding policy to improve economic and environmental outcomes. The project has modelled a matrix of farming systems (north to south and east to west) in New South Wales to determine the effectiveness of different strategies. The intended outcome is the development of a web-based learning tool that is accessible to farmers to integrate information into their decision-making process.

2 Objectives

- Tactical management options and trigger points objectively assessed using modelling and whole-farm economics on a matrix of sites from the rangelands to the HRZ of south-eastern Australia.
- A web-based interactive learning tool to objectively assess the type and timing of tactical decisions for use by producers and extension professionals.
- Scientific and industry publications on tactical management and any products.
- Final report incorporating evaluation of the project.

3 Methodology

3.1 Consultation workshop

Using facilitated interactive process, producers from nine regions across NSW (Table 3.1.1) met at workshops to share their experience and knowledge in managing feed variability, particularly relating to the drought experienced over the previous 12 months.

At each workshop the challenges of decision making under variable and changing climate were outlined and some possible decision triggers derived from previous studies were supplied as an example. Then a representative farming system for each region was identified by participants to be used as the basis for the evaluation of tactical decisions.

Following the presentations, each producer described the strategy they followed over the last one to two years to address the feed deficit currently being experienced. Producers were then asked how they assess the amount and quality of feed they have at hand and to describe the process they go though in deciding whether to feed, sell or agist stock and the prioritisation process they use for different classes of animals. The input was used as the basis to assess the profitability and sustainability of different farming systems and management approaches specific for each region. These scenarios were assessed using modelling and whole-farm economic analysis.

Summaries of each of the consultation outcomes and modelling questions were prepared.

Table 3.1.1. Number of participants in each region

Group	Workshop held at	Number of participants
Orange EverGraze Regional Group	Orange	10
Bookham Ag Bureau	Bookham	8
Monaro Farming Systems	Nimmitabel	11
Southwestern slopes	Temora	12
Central West Farming Systems	Condobolin	11
Homebush Land care group	Balranald	6
Barrier area Rangecare group	Broken Hill	7
Singleton and Dungog Gresford beef groups	Tocal	5
GLENRAC	Glen Innes	5
Total		**75**

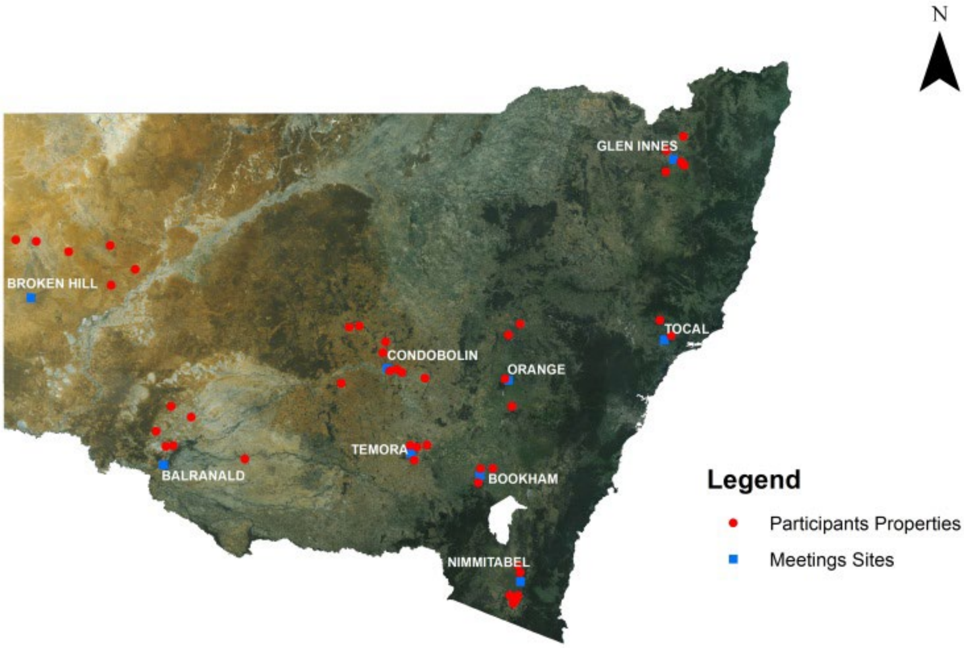


Figure 3.1.1. Map showing the distribution where the 9 consultation were held and the properties of participants.

Figure 3.1.2. Images of a selection of the consultations with different groups. Left: Dungog Beef Group, Centre: Central West Farming Systems and Right: Temora Producer group.

3.2 Modelling

Farming systems and management practices were modelled using AusFarm in all locations, except the rangelands. The GrazPlan simulation models (Moore et al. 1997) were used in AusFarm (version 1.5.1) to simulate the farming systems. The models operate on a daily timestep and consist of a water balance model, pasture growth model, and an animal production model including intake, nutritional requirements, reproduction, and mortality of animals (Freer et al. 1997; Moore et al. 1997; Moore and Ghahramani 2014). The models are dynamic and simulate the interaction of water, cropping, pasture and animals, and the AusFarm framework allows for flexible livestock management to be implemented.

Ausfarm can capture the flexibility farmers make in stocking decisions and the resulting complex systems. Farming system modelling has traditionally focused on biophysical (e.g. herbage mass of a pasture) and time-based criteria for management decisions. However, we know in practice that farmers make different decisions to adapt to seasonal variability and that costs and returns at the time influence decisions. It is for this reason we developed a modelling framework that can address this variability and we have used the key management decisions and the thinking behind these decisions learnt during the consultation process described above.

The base model was run for 110 years (1910 to 2019) for each site and livestock system. Initially, to determine trigger points to activate management decisions, soil moisture, supplementary feeding and pasture production were determined on a weekly basis. To streamline the decision-making processes, green biomass on the 15th of each month was subsequently used to determine trigger points to activate management decisions. Further details on how trigger points were developed in the model can be found in appendix 2.

Management decisions derived from producer consultations included the sale of non-productive (not in lamb or calf) stock, early weaning (cattle only), early sale of offspring, and selling younger cast-for-age stock. The major influence on decision making commonly identified was to maintain animal genetics and flock/herd structure. Therefore, the selling-off of younger cast-for-age animals is usually the last decision to be made. Conversely, when rebuilding the flock/herd, the best approach is to go about it by the usual flock replacement strategy of retaining the usual number of female weaners to maintain age structure. This will enhance stability of the flock/herd (Phil Graham, pers comm).

3.3 Whole farm economic analysis

This project used a stochastic whole-farm simulation modelling framework, which links biophysical modelling data, with simulated price data, to assess the economic performance of different management decisions for up to 16 livestock grazing enterprise systems from nine sites across NSW. This is greater than the nine scenarios planned at the start of the project, due to the diversity of farming systems identified in the consultation phase.

The whole-farm simulation model was run in Microsoft Excel®, with biophysical input coming from AusFarm® (CSIRO 2007), and historical price data from 2010-2020 accessed from multiple sources (MLA 2020, AWEX 2020, ABARES 2020). Variable costs were calculated using data from NSW DPI gross margin budgets (NSW DPI 2020). Biophysical outputs generated by the AusFarm® simulation model and related software packages in the GrazPlan suite of decision support tools have previously been validated or verified under a range of livestock and cropping systems in NSW (Mokany *et al* 2009, Heard *et al* 2013, Cashen *et al.* 2015, Broadfoot *et al*. 2017, Roberston and Friend 2020), in most locations established models were used (see section 4.2 for additional detail). AusFarm® simulations were run using historical climatic data (1910–2019) for the sites obtained via Datadrill (Jeffrey et al. 2001). In order to create enough simulation iterations to adequately represent the between year variability within the production systems, while maintaining the inter-temporal integrity, the 110 years of weather data was Monte Carlo sampled prior to running it through the AusFarm Model. This process created 10 x 110year weather files which were then sampled in 5-year sequences in the economic simulation model.

A representative case study approach (Nuthall 2011) was used to design model farms, based on information provided by farmers as outlined in section 3.1. Daily time-step data was aggregated into monthly summaries for use in the livestock trading schedules and economic model. The first 10 years of each 110 year AusFarm data run was discarded (used as a run-in to normalise the AusFarm® model), leaving 200 x 5-year string of successive and sequential biophysical year outputs which were them match with Monte Carlo sampled price data. This process was repeated to give a total of 600 x 5-year iterations. This approach was used to overcome the limitations Monte Carlo sampling and the impact of underestimating the sequential impacts of resource utilisation within the biological system (Amidy et al., 2017).

The economic simulation model used 10 years of CPI adjusted (2020 AU$) historical price data (Jan 2010 - Dec 2020) to populate the price model. To assess the impact of a high, medium and low-price outlook for the DSS tool, prices were ordered from high to low, with the highest ⅓ of price distribution allocated to the higher price outlook, the centre ⅓to the medium and the bottom ⅓ to the low-price outlook respectively. A summary of the price data can be found in appendix 4. For the DSS tool, price data was Monte Carlo sampled from within the high, medium and low-price categories for the relevant scenario. For the general population analysis of sites and systems data was Monte Carlo sampled from the entire historical price dataset. A single price was allocated to each variable for a given calendar year within the simulation. Thus, while the inter-annual price was stochastic, the intra annual price within any year was static.

Further details of the analysis can be found in appendix 4.

3.4 Lookup Table

Using the information gathered from producer group consultations, the modelling process and whole-farm economic analysis, a stocking decisions and tactical management learning tool that will be readily accessible to farmers was developed.

The tool will allow different management actions to be assessed and the probability of meeting profit and environmental targets evaluated using metrological data, livestock prices and feed cost. The process is designed to generate a tool that is regionally specific to assist producers in making informed decisions around feeding and selling under different scenarios.

Producers will be able to select the region, type of enterprise, seasonal conditions and prevailing livestock prices and feed cost and time of the year before making selection of the possible decisions. The tool will also provide enough background information so that producers are able to clearly understand the system and decisions.

The lookup tables have been developed in Excel®. They will be developed into a web format with the redevelopment of other NSW DPI drought management tools, to ensure integration with these established tools and processes.

3.5 Rangeland modelling and analysis

Modelling tactical decisions in rangelands was initially planned to be done with the AusFarm model. However, due to the complexities of the model and the limited time in the project to integrate browse in the diet into the model, the SGS pasture model was instead used. The SGS model has not been previously used in the southern rangelands. The method for validating the use of the SGS model in this environment and determining timing and criteria for tactical management decisions at Balranald against producer comments is outlined in Appendix 3.

Like AusFarm, the SGS pasture model incorporates a physiological model of pasture species herbage growth in response to climatic conditions; the water balance including evapotranspiration, runoff (surface and subsurface), infiltration and drainage. Pasture utilisation by grazing animals; a metabolisable energy-based animal growth model; and organic matter and inorganic nutrient dynamics (for nitrogen, phosphorus, potassium and sulfur) including plant uptake, adsorption, leaching, nitrogen fixation by legumes, and atmospheric nitrogen losses are also included. A range of grazing options (set-stocking, rotational grazing and continuous grazing at a variable rate) is available for ewes and lambs and wethers, however, management options are much simpler than can be implemented in AusFarm. Each of the main modules (water, nutrients, pastures and animals) is interconnected. The model is hierarchical in structure and most processes are described in terms of a series of fluxes (or, more specifically, flux densities) that have dimensions of amount per area per time (Johnson et al. 2003).

The system investigated in the analysis was Merino ewe (60 kg reference weight) joined to a terminal sire with lambing on the 1 June and lambs sold on the 1 November or at 50 kg and run at stocking rate of 0.1 ewes/ha. The pasture in the model was a C4 native grass and subclover (representing naturalised/native annual grasses and forbs) that had been calibrated to represent the forage supply with browse from perennial shrubs (e.g. *Atriplex spp.*). The soil used had light hydraulic and low organic matter properties. Weather data was downloaded from long paddock for the Balranald with an average annual rainfall of 317 mm. While this area has a low level of trees, the tree level was set at 30% to account for the natural patchiness of semi-arid rangelands, which concentrates and retains resources into fertile patches that are interspersed with bare areas. The simulation was run from 1910 to 2019.

A simple gross margin analysis was done on the biophysical model output using cost and prices from NSW DPI 2020 gross margins. The sheep prices and feed grain prices were assessed against High, Medium and Low CPI adjusted prices for the last 20 years. The sheep meat and the feed grain prices were based approximately on the 0.9 decile (High), average (Medium) and 0.1 decile (Low) years (Table 3.5.1). The gross margins per DSE are reported, where the long-term average DSE of the system is used (rather than individual DSE in a particular year). It is important to note that the SGS model used feeds to optimum animal performance, so differences in profitability are primarily driven by differences in the cost of supplementary feeding rather than production differences between treatments.

Table 3.5.1. Sheep meat prices and feed grain prices used in High, Medium and Low analysis scenarios.

Category	High	Medium	Low
CFA ewe sale ($/kg cwt)	$6.35	$3.30	$1.50
Light lamb sale ($/kg cwt)	$7.50	$5.00	$3.00
Replacement ewes ($/hd)	$220	$125	$60

Feed grain ($/t)	$350	$264	$200

4 Results

4.1 Producer workshops

The workshops helped to identify the decision-making process producers use for tactical decision making, identified tactical decisions that had made in the last 12 months and prioritised those that have the greatest chance of increasing profit or were the hardest to make. The location of the workshops and the number of participants who attended are presented in Table 1. Figure 1 shows the distribution of properties that participated in the discussion.

The summaries of each consultation outcomes and the modelling question derived from discussions are presented in appendix 1. A synthesis of the findings across sites is shown below. The consultation could be broken up into information about the decision-making process, the influence of strategic investment on the decisions that could be made, the decisions that producers had made in recent droughts, and what is required to help with improved decision making.

4.1.1 The decision-making process

Box 4.1.1: Selected producer comments that capture key sentiments about decision making made during the producer consultations.

Producer 1: *"It's not about the decision you make but the process you go through"*
Producer 2: *'High livestock prices make a difference to decision making'*
Producer 3: *"It's generally better to make a poor decision then not make one at all"*

4.1.1.1 What do producers assess?

The common criteria that producers are assessing when they make tactical decisions include:

- pastures for quality and quantity (nearly always subjective)
- animal condition score and growth rates
- estimations of animal requirements (from pasture or supplement)
- market information (price and trends)
- agistment availability
- fodder stored (silage and hay)
- financial position (cashflow requirements)
- rainfall records (determining how dry it is compared to previous experience)
- soil moisture probe information (these have been deployed in many regions by farming systems groups such as Monaro Farming Systems and LLS)
- forecasts – but only used as a general guide
- total grazing pressure (rangelands)

4.1.1.2 How do the producers use this information in decision making?

From the information that the producers assess in tactical decision making there are several ways that they pull this information together. The most common way identified was to use their previous experience and value-based judgements on when they need to enact a management change, including the start of supplementary feeding or the sale of livestock.

Some producers identified the use of critical dates (e.g. "if it has not rained by 15 August then we will sell cast for age ewes early") to ensure they stick to making timely decisions. They felt that this helped to take some of the emotion out of the decision-making process. For producers in the southern tablelands and Monaro, key times for decisions include late autumn on the lead into winter feed deficits and in mid spring as soil moisture runs out in dry years and feed quality and availability declines. In more arid regions the mid spring decision point was earlier (e.g. August at Balranald) and the pre-winter decision point was less important. How these decision dates were incorporated into the modelling process is shown under section 4.2.

For producers who were using grazing charts that are commonly part of holistic grazing systems, rolling rainfall (DSE per 100 mm of rainfall) was an important metric. Some of these producers made general statements about the level of feed that they liked to have in front of them (e.g at least 3 months feed) but the process for assessing this was not always clear and was likely based on estimations of the grazing days in front of them obtained using grazing charts rather than any formal budgeting process.

Some producers used tools like the Drought Feed Calculator to determine the amount and cost of supplementary feed. Others used seasonal updates (tactical model runs based on feed-on-off and current soil moisture) run by farming systems groups to determine the likelihood of pasture growth meeting animal demands.

Many producers highlighted the importance of discussing the information with neighbours, friends, or producer groups. There were occasions where consultants were used to help with tactical decisions, but this was not common.

4.1.1.3 What are people thinking about?

Producers considered three things when assessing tactical decisions to adapt to feed deficits. These were the requirements of their animals, the condition of their country and financial requirement of their business and family situation.

When considering their animals, there were a few issues that were important. The value of the genetics was identified as being a key consideration and producers were more likely to retain animals and feed them if they had invested heavily in their genetics. If producers traded livestock regularly then they were more inclined to sell down their livestock to a lower number of animals. The time in the production cycle was also a key driver in the decisions that could be made. Of the producers who were considering selling versus feeding decisions, they considered the cost of purchasing livestock after the drought breaks, they also considered the cost of supplementary feeding and the time it will take. There were producers who made decisions based on their interests and skills. For example, they did not like supplementary feeding, they had limited experience with it and so they opted to sell livestock to address feed deficits. This even extended to issues like sourcing supplementary feed when supplies were short and some producers relayed stories of significant differences in the amount paid for supplementary feed by producers in the same region, due to differences in experience and networks.

The condition of the country was a major consideration for producers making tactical decisions to adjust to feed deficits. Many discussed the desire to maintain reasonable levels of ground cover. They also expressed disappointment when ground cover was not able to be maintained due management decisions they had made. Maintaining ground cover often required removing animals from grazing paddocks and selling was a common practice, but other producers used containment feeding lots and sacrifice paddocks for supplementary feeding.

There were business considerations that influenced tactical decisions also. The risk of supplementary feeding was often mentioned, which appeared to be an aversion of spending money in a drought, possibly due to real or perceived issues with borrowing. The requirements of the business also influenced how much people pushed production during these periods of deficit. Issues about access to labour were also a consideration when committing to long-term feeding.

4.1.2 Strategic investment and tactical decisions

Preparation in good seasons determines the options producers have in poor seasons. This was highlighted clearly in a quote from one producer. “Decisions made 10 years ago to buy machinery to allow for hay making, silos bought to store grain determine the tactical decisions we make now”. There are several methods of preparation that were identified. Producers highlighted the importance of Farm Management Deposits (FMDs) as a reserve used to buy grain. This was a common practice identified in several of the regions, but a shortage of grain in the most recent drought made some producers question whether further investment was needed in grain storage. Many producers in the high rainfall zone stated that it was not common for them to conserve fodder. However, in the mixed farming regions harvesting and storing grain and hay was common, with many identifying minimum benchmarks for the amount of grain to store for their own use (e.g. a bag of grain per year for every sheep). The recent investment in farm feedlots or droughtlots has given producers options to feed animals and protect the country and this was viewed as a positive.

4.1.3 Tactical decisions made in recent droughts

When making tactical decisions producers identified to either sell livestock or to feed them with most producers using a combination of both options.

Things producers considered when making selling decisions (and purchasing decisions if trading) include:

- critical dates are often before winter (winter feed gap) and mid-spring (if soil moisture is running out);
- make incremental adjustments – first round culls, marketable stock (highest returns), then progressively sell through older or poorer preforming stock;
- using wethers as a release valve; and
- reducing sale weight targets to lighter lamb/cattle markets.

Things producers consider when feeding:

- confinement feeding to protect the country;
- bailing failed crops rather than grazing; and
- early weaning or not joining young ewes to reduce requirements when feeding.

Other options producers considered when adapting to feed deficits:

- growing more feed while you can by using gibberic acid and N to boost winter feed while there is moisture;
- early shearing (aiming for >60 mm staples) before sale;
- leasing stock to a producer in another region – to avoid problems with availability and price of stock when it rains; and
- sourcing agistment if available.

4.1.4 What will help with tactical decision making

At the end of the consultations the groups were asked what they thought would help to make better tactical decisions. The responses fell into five broad categories. 1) Farmers highlighted that they required daily updates on their feed position including demands from livestock, often describing this as something like pastures from space (Satellite derived pasture dry matter estimations) that includes animal demands, but few had previously used this service (possibly because it did not consider the demand side from livestock on-hand). 2) There was an overwhelming request for better weather and climate forecasts, and they felt that there was poor predictive capacity beyond a week. 3) Some groups specifically mentioned the usefulness of the NSW DPI drought feed calculator and requested further development of this tool to include the current amount of pasture available (this development has since been made). 4) There were requests for more up-to-date information on government services (e.g. on adapted pasture species and reliable market information). 5) They also wanted exposure to information and experience that helps to make good decisions (e.g. interaction with other farmers who are making these decisions).

4.1.5 Synthesis of information

When developing a system to adjust to seasonal variation there are strategic and tactical considerations. Key points, gleaned from the workshops, that producers should consider are outlined below.

Strategic:

- Ensure stocking rate is appropriate for the expected range of seasons.
- Structure enterprises to be able to tactically reduce grazing pressure without impacting on livestock numbers in the long-term.
- Invest in the good times:
    - Develop a farm feedlot/droughtlot (to protect your pasture when feeding);
    - Buy grain when cheap;
    - Use FMD's or have capacity to borrow to purchase grain;
    - Develop productive pasture (use moisture more efficiently);
    - On-farm storage and feeding systems; and
    - Store grain and high-quality hay/silage.

Tactical:

- Develop a system that helps to understand:
    - quantity and quality of feed-on-offer;
    - future pasture growth; and
    - current and future animal requirements to identify early when decisions should be made.
- Make incremental adjustments to animal numbers regularly in response to declining feed availability, rather than holding on and selling a larger portion of herd/flock later.
- Calculate feeding and selling decisions based on the immediate situation and future production requirements. In doing so:
    - Know the quality of your genetics;
    - Project the cost of replacement stock into the future;
    - Know the value and production of each class of stock;

  - Determine the cost of supplementary feed in relation to animal production (avoid poor quality feeds).
- Look for opportunity to grow extra feed when moisture is available.
- Use agistment or leasing of stock to manage variation where possible.

4.2 Modelling outcomes

As shown above, producers consider animal requirement, condition of property, financial situation and personal value (belief) when making tactical management decisions (Figure 4.2.1). The project team used these key management decisions and the thinking behind them to develop modeling framework that can adapt livestock numbers to seasonal variability, and this was compared to a baseline system. While modelling questions were derived from the consultations (Appendix 1), they were not the primary focus of the analysis.

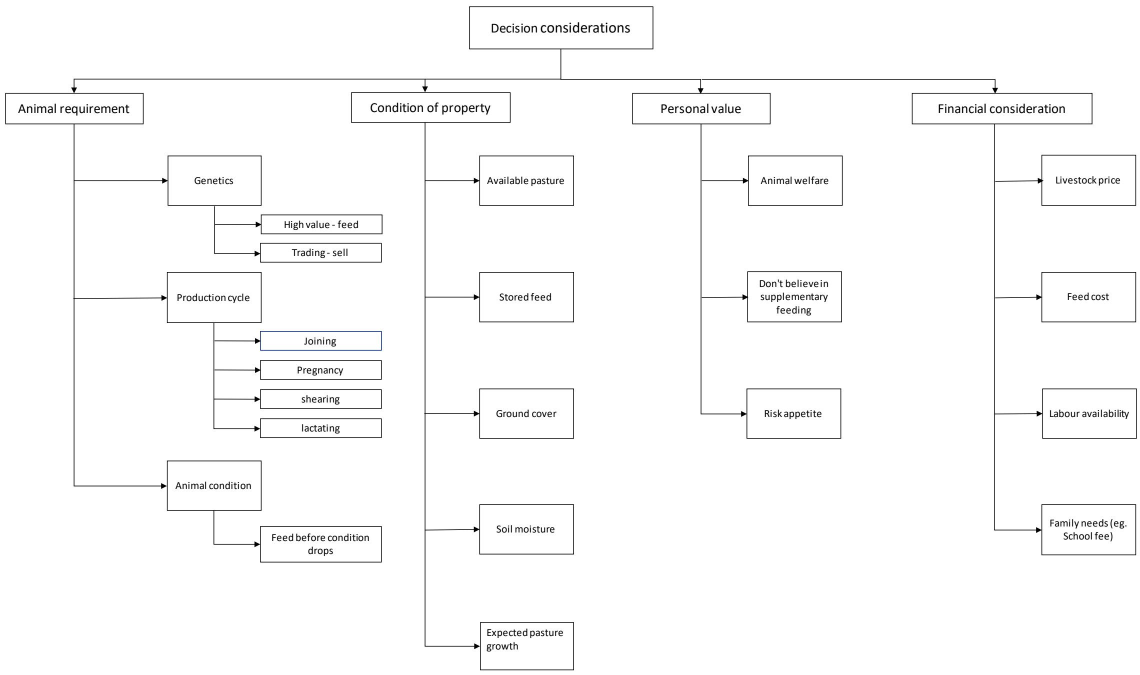


Figure 4.2.1. Producer's decision-making process

The development of models for each site was influenced by what models (if any), were available for each site, and transferring these into the Ausfarm® framework, with producer group input into further developing the whole farm system. This varied from site to site (Table 4.2.1), and full descriptions and timelines, are provided in subsequent sections.

Table 4.2.1 Previously developed models that were adapted to the current project based on producer group consultation

Site	Previous models	Reference
Orange	AusFarm - EverGraze	Broadfoot *et al*, 2017
Monaro Farming Systems	GrassGro	P Graham
Bookham	GrassGro	P Graham
Temora	AusFarm	Cashen *et al* 2015
Glenrac	none	-

Central West Farming Systems	AusFarm	Cashen *et al* 2015
Tocal	none	-

Grazing management was determined by the feed-base available and livestock class, to ensure that supplementary feeding only occurred for the livestock class that required it.

To help visualize each livestock production system and determine what management decisions could be made in response to trigger points, timelines were developed for each site and livestock system Figure 4).

The outcomes of the modelling process for each site are shown below.

4.2.1 Orange EverGraze Regional Group

The outcomes from the producer focus group highlighted the need to focus on decisions in sheep and cattle only systems, as maintaining the dominant system during drought will be the focus of producers. Key themes from the consultation include ensuring critical dates are used and making decisions incrementally, often involving several steps as conditions unfold. For the cattle system the inclusion of early weaning was a key interest, while at other times of the year the management decision was driven by the stage in the production cycle. Multiple tactical decisions were combined to assess a flexible destocking system compared to a baseline feeding system for both sheep and cattle models.

The AusFarm model developed for EverGraze (Broadfoot *et al*, 2017) was used as the basis for this site, but was updated based on input from the producer group to contain an oats fodder crop and phalaris pasture on more productive areas of the landscape. The farm comprised of 1000 ha, split up into 23 paddocks. The soil type used was a brown chromosol as described by Badgery *et al* (2017). To enable cropping to occur and determine soil water, APSoil #179 from Temora was used and modified.

Paddocks 1 to 10 (Rot1 to Rot10) use the complete APSoil #179 down to 1800 mm. Oats is sown for 2 consecutive years for grazing and grain, then a phalaris base pasture is sown. Paddock size is 50 ha. Grazing of oats up to Zadocks scale of 6.0 (early August)

Paddocks 11 to 20 (Micro1 to Micro10) use APSoil #179 down to 1200 mm. Paddock size is 30 ha.

Paddocks 21 to 23 (Danth1 to Danth3) use APSoil #179 down to 450 mm. Paddock size is 65 ha.

Fertility factors in AusFarm were used to refine potential pasture growth for the pastures in different paddocks, with the higher the fertility factor, the greater potential pasture growth. The fertility factors used are describe in the table below (Table 4.2.1.1).

Table 4.2.1.1 Fertility factors used for individual species in the Orange models

Paddocks	Phalaris	Microlaena	Danthonia	Subclover	Annual Ryegrass
Rot1 to Rot10	0.8	0	0	0.65	0.65
Micro1 to Micro10	0	0.6	0	0.46	0.47
Danth1 to Danth3	0	0	0.54	0.1	0.1

Long-term (1900-2019) annual mean rain was 811 mm.

This farm was used for 2 models – Orange cattle and Orange sheep.

The models were run from 1910 to 2019, with total green biomass, soil moisture and supplementary feeding determined for the sheep model, and total green biomass on the 15th of each month determined for the cattle model. Relationships between these factors with management decisions were used to determine decision points.

4.2.1.1 Orange Sheep

This was the first model developed and was used to help develop decision points (details shown in appendix 3) as producers often made these decisions subjectively and we examined ways to reflect what they were assessing at the time, which was often related to feed and moisture deficits. Consequently, not all the decision points were included.

Self-replacing merino flock, of which 25% of ewes joined to terminal sires. Joining starts from April 1, for 42 days, to lamb in September. Weaning is at 98 days (December). Normal shearing is in May. Merino wether lambs are sold at weaning, as are CFA ewes. Terminal lambs are sold at 42 kg, up to May 30. Excess merino ewe lambs (less those kept as replacements) sold by November 30.

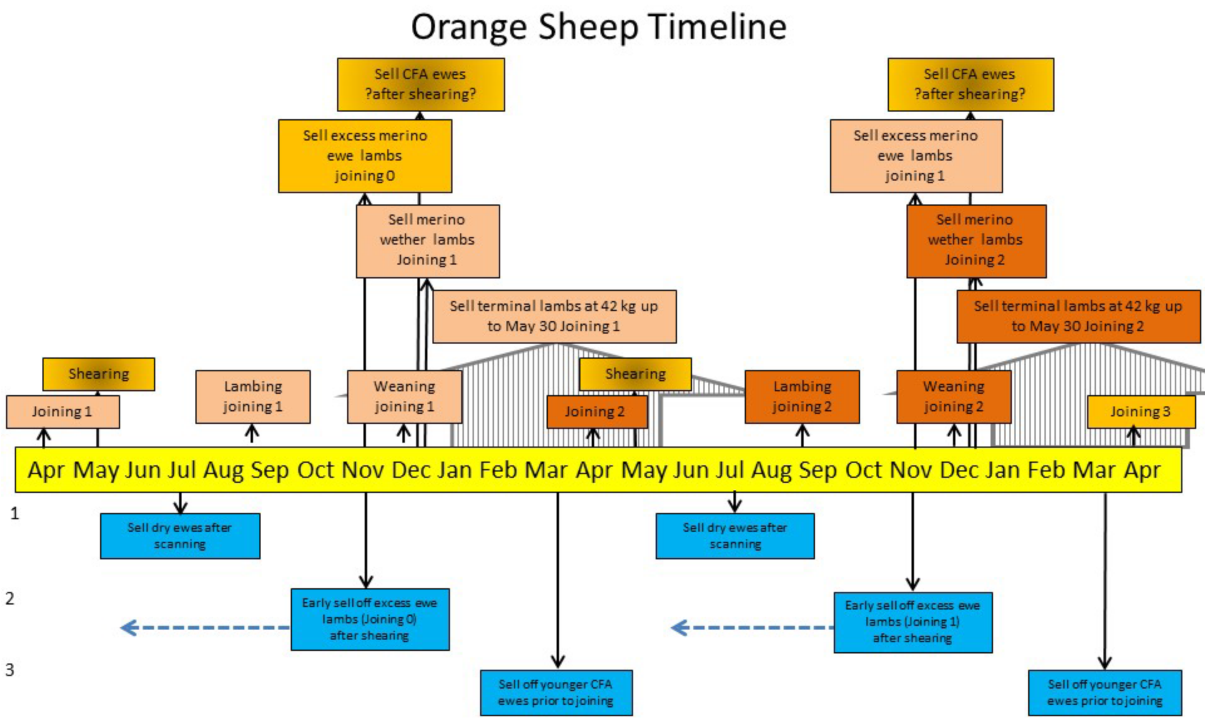


Figure 4.2.1.1.1. Decision timeline over two years for Orange sheep production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points. The blue dashed horizontal arrows below the yellow shaded month bar indicate change in sale times in response to trigger points.

Decision protocols for flexible decisions:

1. Sell-off of dry ewes after scanning. All ewes are scanned 3 months after joining and split into dry, single or twin bearing. All dry ewes (older than 2 years) are sold after scanning in July. This allows maidens a "second chance".

2. Early sell-off of excess merino ewe lambs in June after shearing, depending on available green feed at the 31 May. If available green feed is on average < 500 kg DM/ha, early sale occurs, otherwise normal sale is November.

3. Sell-off of younger cast for age ewes. Normal CFA is 6 years, younger CFA is 5 years. Two factors were selected to determine if younger CFA were to occur – relative soil moisture and supplementary feeding, during the first 3 months of the year prior to joining. If soil moisture during this period was < 40%, and stock were supplementary fed during this period, sale of younger CFA. (Note that if supplementary feeding occurred in the first 3 months, then it was highly likely that it would continue until the following spring, as cooler temperatures prevented pasture growth despite any significant rain).

4.2.1.2 Orange cattle

The Orange cattle system was based on Angus cows and calves. Joining starts on November 1, for 60 days, to calve in August. Weaning was at 8 months (April). Weaners were sold from April 15 when they reached a target weight of 300 kg, up to July 30 when any remaining were sold. CFA cows sold at 10 years old on April 15.

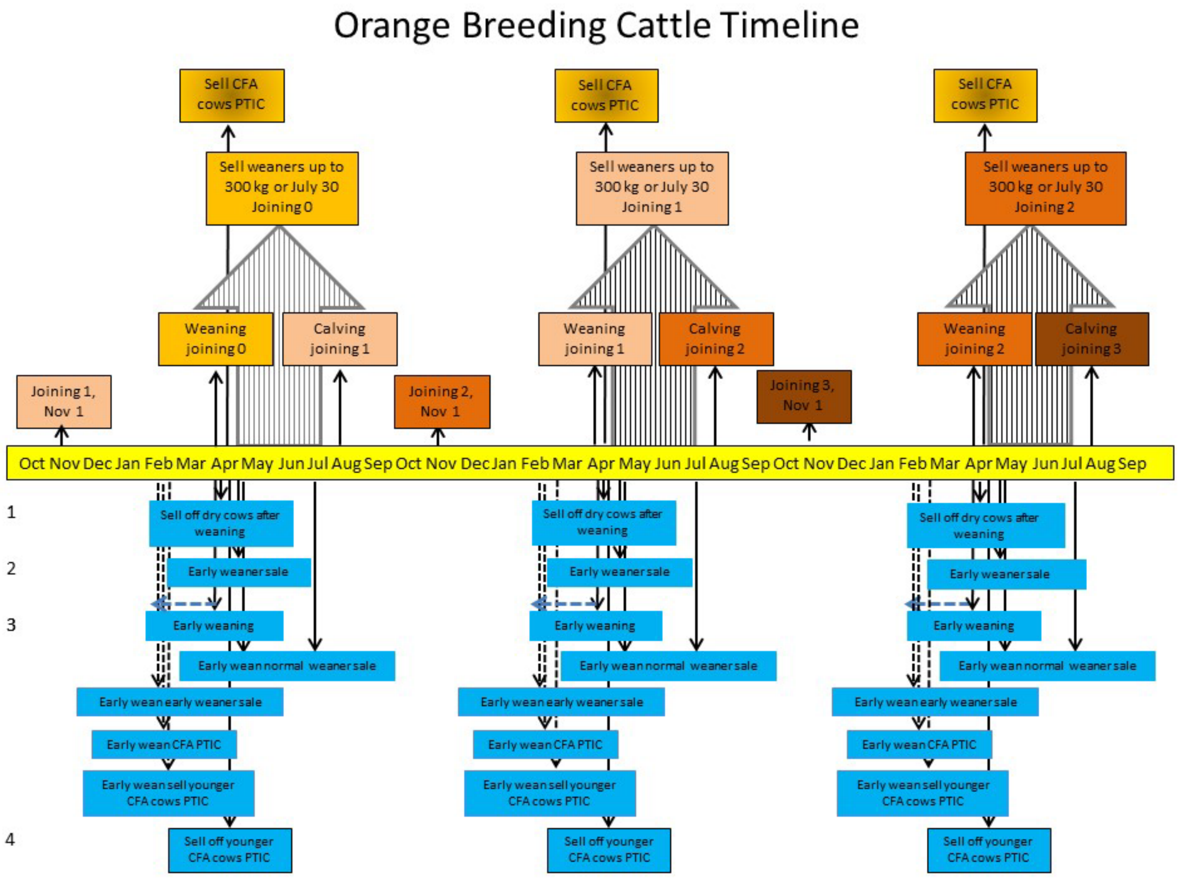


Figure 4.2.1.2.1. Decision timeline over three years for Orange cattle production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth,

weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points. The blue dashed horizontal arrows below the yellow shaded month bar indicate change in weaning times in response to trigger points, while the black dashed vertical lines indicate the susequent change in sale times due to early weaning.

4.2.1.3. Development of trigger points

The model was run from 1910 to 2019, with total green biomass calculated on the 15th of each month. This monthly total green biomass was divided by cow number for the farm * 20kg (approximate cow and calf unit daily feed requirement) to obtain a monthly graze_days. Relationships between monthly graze_days and management decisions were used to determine decision protocols.

Decision protocols for flexible decisions:

1. Sell-off dry cows after weaning. All cows are scanned on March 28, with cows not in calf assigned as DRY_COW. After weaning (April), dry cows are sold.
2. Early weaner sale. Total green biomass is determined on April 15 to determine April_graze_days. If April_graze_days < 20, weaners are sold early on April 29, otherwise normal sale from April to July 30.
3. Early weaning. Total green biomass is determined on January 15 to establish January_graze_days. If January_graze_days < 20, early weaning occurs on February 15 (ie weaning at 6 months), otherwise normal weaning occurs on April 15.
   i. If early weaning occurs. Total green biomass is determined on February 15 to work out February_graze_days. If February_graze_days < 20, weaners are sold on February 28, otherwise normal sale from April to July 30.
   ii. If early weaning occurs early sale of CFA cows occurs on February 20. These cows are pregnancy tested at scanning and in calf (PTIC), as compared to dry cows sold in decision 1.
4. Sell-off of younger CFA cows. If normal weaning occurs, April_graze_days is used to determine the age of CFA cows. If April__graze _days > 40 days, CFA age is 10 years; if > 20 and < 40 days, CFA age is 8 years; if < 20, CFA age is 6 years. With early weaning, February_graze_days is used. If February_ graze _days > 20 days, CFA age is 10 years; if < 20 and > 10, CFA age is 8 years; if < 10 days, CFA age is 6 years. All these cows are PTIC.

4.2.2 Monaro Farming systems

The producer focus group identified the need to focus on decisions in self-replacing sheep production systems run at low rainfall (Bungarby) and high rainfall (Delegate) sites of the Monaro. The critical decision points identified were early summer as soil moisture declines and autumn, when level of feed going into winter can be determined. While producer's values such as 'I don't want to supplementary feed', were a key theme in the consultation process, we were not able to compare those perceptions with the most rational (profitable) decisions. Instead, a flexible destocking system was compared to a baseline feeding system similar to Orange. The flexible destocking systems were set up around timing and the tactics used by the producers in the area including: the early sale of lambs, the early sale of CFA wethers and the sale of younger wethers, and the sale of two age classes of CFA ewes.

Two models, Bungarby and Delegate, were developed based on GrassGro models previously used at these locations; Delegate improved, Bungarby improved and Bungarby native. These models were then developed further based on information from the producer group consultations. Each farm was 1000 ha, split into 10 paddocks of 100 ha.

4.2.2.1 Livestock system

Self-replacing merino system with a wether proportion was used for both sites. For Delegate, ewe stock rate was 6.9 ewes/farm ha, with wethers at 2.3/farm ha, while for Bungarby ewe stock rate was 5/ha with wethers at 1.25/ha. Joining was 15 April, with weaning 15 December, with normal shearing on 1 April. Weaned ewe lambs (hoggets), not kept as replacements, were sold 14 December, while weaned male lambs, not kept as replacements, were sold from 16 April when they reached a weight of 50 kg, until 31 June when any remaining wether lambs were sold.

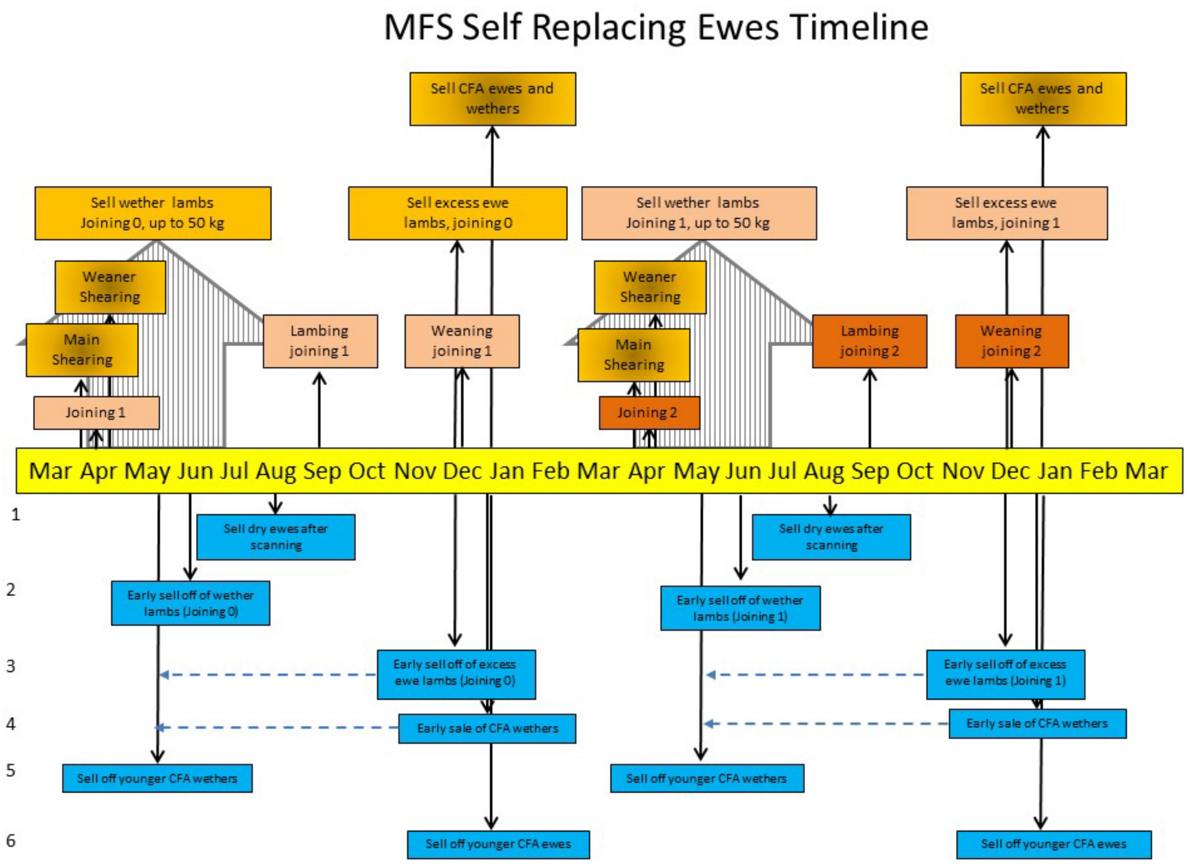


Figure 4.2.2.1. Decision timeline over two years for Bungarby and Delegate sheep production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points. The blue dashed horizontal arrows below the yellow shaded month bar indicate changes in sale times in response to trigger points.

Bungarby pastures and grazing management

For the Bungarby model, 5 paddocks (Native1 to Native5) had a soil type of "Bungarby unfertilised Poa", with pastures based on *Poa sieberiana*, *Austrostipa* spp, Paraggio barrel medic (*Medicago truncatula*), and subclover (Seaton Park). The other 5 Bungarby paddocks (Improved1 to Improved5) had a soil type of "Nimmitabel Basalt soil", with pastures based on phalaris, fescue, subclover (Mt Barker), and annual ryegrass.

Paddock allocation is described in Table 4.2.2.1. Native 1 to Native 5 were allocated predominately to the wethers (N paddocks), while Improved1 to Improved5 were allocated to ewes and lambs (I paddocks).

Table 4.2.2.1. Paddock allocation for different livestock classes to native (N) and introduced (I) paddocks at different times of the year in the Bungarby model.

Period	Ewes	Weaners/ Hoggets	Ewe Replacements	Dry ewes after scanning (in managed model)	Wethers	Wether Replacements	Comments
Jan 1 to Mar 31	Follow N	Best I	Best I	Follow N	2nd Follow N	Best N	Post weaning
Apr 1 to Apr 15	Best I	2nd Follow I	2nd Follow I	Best I	Follow N	Best N	Flushing
Apr 15 to Jul 10	Best I	2nd Follow I	2nd Follow I	Best I	Follow N	Best N	Joining to scanning
Jul 11 to Dec 15	Best I	2nd Follow I	2nd Follow I	Follow N	2nd Follow N	Best N	Scanning to weaning
Dec 16 to Dec 31	Follow N	Best I	Best I	Follow N	2nd Follow N	Best N	Post weaning

Delegate pastures and grazing management

The Delegate model soil type was “Jefferies Old Pasture” with pastures based on annual ryegrass, subclover (Seaton Park), fescue and phalaris.

Paddock allocation is described in the following table (Table 4.2.2.2), paddocks 1 to 6 were allocated to the ewes and lambs (E paddocks), while paddocks 7 to 10 were allocated to the wethers (W paddocks), predominately, except for ewes after weaning and dry ewes post scanning.

Table 4.2.2.2. Paddock allocation for different livestock classes to ewe (E) and lamb (L) paddocks at different times of the year in the Delegate model.

Period	Ewes	Weaners/ Hoggets	Ewe Replacements	Dry ewes after scanning (in managed model)	Wethers	Wether Replacements	Comments
Jan 1 to Feb 14	Follow E	Best E	Best E	Follow E	2nd Follow W	Best W	Post weaning
Feb 15 to Mar 31	Best E	2nd Follow E	2nd Follow E	Best E	Follow W	Best W	Flushing
Apr 1 to Jun 27	Best E	2nd Follow E	2nd Follow E	Best E	Follow W	Best W	Joining to scanning
Jun 28 to Nov 17	Best E	2nd Follow E	2nd Follow E	Follow W	2nd Follow W	Best W	Scanning to weaning
Nov 18 to Dec 31	Follow W	Best E	Best E	Follow W	2nd Follow W	Best W	Post weaning

4.2.2.2 Development of trigger points

The basic model was run for 110 years for both sites. Total green pasture production was determined on the 15th of each month for the improved (“I” paddocks) and native pastures (“N” paddocks) separately for Bungarby, and for the E paddocks and W paddocks for Delegate. Total green pasture for the I paddocks and E paddocks were divided by the anticipated ewe number (ewe stocking rate * farm area) to determine the monthly ewe trigger, while total green pasture for the N paddocks and W paddocks were divided by the anticipated wether number (wether stocking rate * farm area) to determine monthly wether trigger. The relationships between these values and management activities were investigated to quantify the trigger points.

Decision protocols for flexible decisions:

1. Sell dry ewes after scanning. Ewes are scanned mid-gestation, and dry ewes older than 2 years are sold two weeks after scanning in August.
2. Early sale of wether lambs. Normal sale is from April 16 to June 30 (50kg lamb). If March ewe trigger and April ewe trigger < 20, all wether lambs were sold on May 1, after weaner shearing.
3. Early sale of excess ewe lambs. Normal sale is December 14, prior to weaning of next cohort of lambs. If June ewe trigger <70, sell excess ewe lambs on June 16.

4. Early sale of CFA wethers. Normal sale is January 2. (Note that an early sale of CFA ewes does not occur as it needs to happen after weaning). If May wether trigger < 50 (Bungarby) or < 40 (Delegate), CFA wethers are sold on May 16.
5. Younger sale of CFA wethers. Normal CFA age is 4 years. Younger sale of CFA wethers only occurs when early sale of CFA wethers occurs, as there appeared to be no relationships at the normal wether CFA sale. If April wether trigger point < 10, wether CFA age drops to 3 years.
6. Younger sale of CFA ewes. Normal age is 6 years. If November ewe trigger < 200 and December ewe trigger < 175 (Bungarby) or 200 (Delegate), ewe CFA age drops to 5 years.

4.2.3 Southwestern slopes

Through the focus group consultations producers identified that baseline systems with grain storage and feeding to get through feed deficits were more profitable than systems that destocked as a result of higher stocking rates (due to retaining ewes and the sale of heavier lambs). The producers emphasized the development of infrastructure and machinery to ensure supplementary feed was on hand when required. This is supported by statements like '[Storing grain] is critical – flexibility in sale of grain and storing for livestock production' and 'No storage, no choice'.

The model was developed from the Temora acceptability AusFarm model (Cashen *et al* 2015) and then adapted based on input from the producer consultations. The 2000 ha farm was split into eight 250 ha paddocks using APSoil #179. Lucerne (L) was the pasture in rotation with wheat (W), canola (C), and barley (B) – $LLLWCWBW_{undersownL}$. Except for the wheat undersown with lucerne, the other 2 wheats in the rotation were dual purpose and were grazed. Livestock system was 50% self-replacing merino, and 50% first cross ewe.

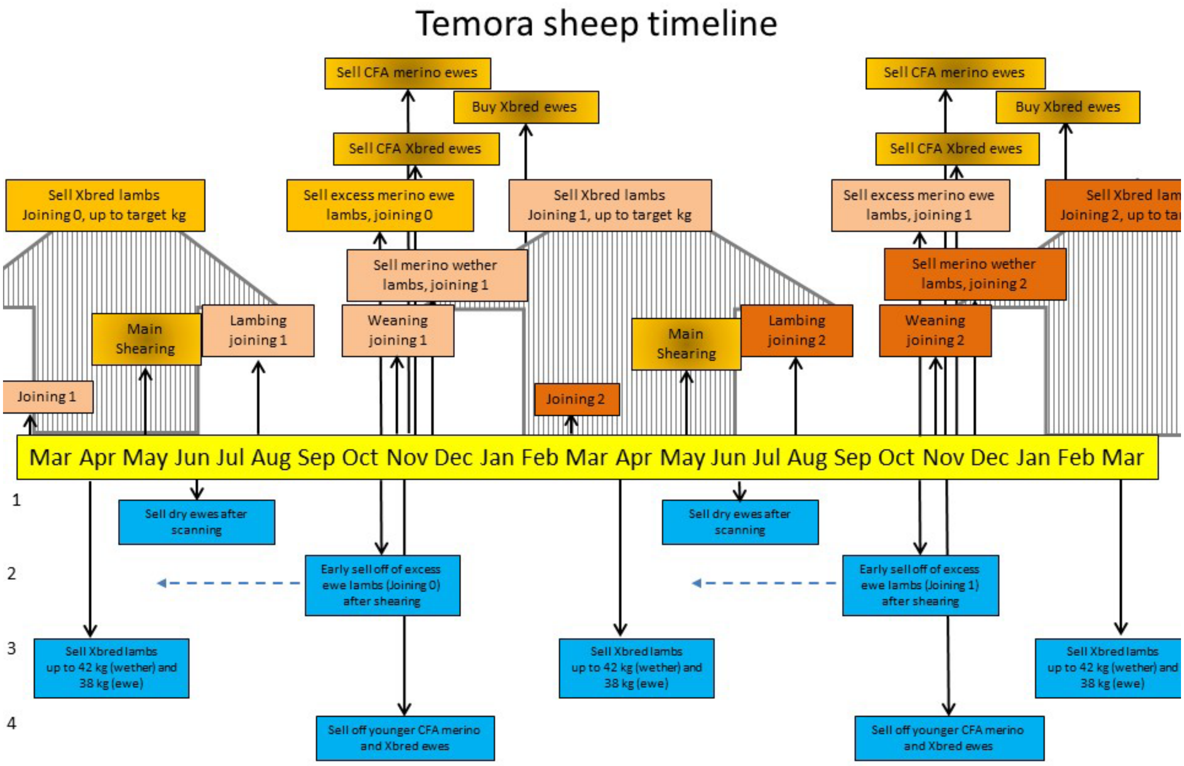


Figure 4.2.3.1. Decision timeline over two years for Temora sheep production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points. The blue dashed horizontal arrows below the yellow shaded month bar indicate changes in sale times in response to trigger points.

4.2.3.1 Development of trigger points

The basic model was run for 120 years. Total green pasture production (lucerne and subclover) was determined on the 15th of each month for each paddock. Total green pasture was divided by the anticipated ewe number (ewe stocking rate * farm area) to determine the monthly ewe trigger. Note that no distinction was made between the merino and first cross ewes. The relationships between these triggers and management activities were investigated to determine trigger points.

Decision protocols for flexible decisions:

1. Sell dry ewes after scanning. Ewes are scanned mid-gestation, and dry ewes older than 2 years are sold two weeks after scanning. Ewes were previously scanned but dry ewes were not allocated.
2. Early sale of excess ewe lambs. Normal sale is November 01, prior to weaning of next cohort of lambs. If April and May trigger <50, sell excess ewe lambs on June 1.
3. Sell prime lambs at lower target weight. Normal prime lamb sale target weights are 52 kg for wether lambs and 44 kg for ewe lambs. When January trigger <50, wether prime lambs are sold at 42 kg, and ewe prime lambs are sold at 38 kg.
4. Sell younger CFA ewes. If January trigger < 50 and February trigger < 50, younger CFA ewes are sold on February 28.

4.2.4 Bookham Ag Bureau

The producer focus group consultation identified that the proportion of wethers in a sheep production system was a key issue during a drought. Wethers are considered a 'release valve' as they can be sold without impacting on the core breeding flock. The standard practice in this region is to have 20-30% wethers, but producers were considering different proportions. Also, in this region supplementary feed is largely purchased rather than conserved. The group identified that Farm Management Deposits were an important reserve to buy grain; and the different feed grain scenarios in the analysis, helped to examine the impact of different buying strategies. Another strategy commonly used was early shearing and sale of excess sheep, which was built into the flexible sale decisions.

This model was developed from the Bookham GrassGro models supplied by Phil Graham and then adapted based on producer group consultation. The farm was 500 ha, split into 10 paddocks of 50 ha each, with soil type a sandy loam over heavy clay (CSIRO described Bookham P demonstration site at "Kia-Ora"). Pastures based on Microlaena, subclover (Seaton Park), and annual ryegrass.

A self-replacing merino livestock system has joining starting on April 1, lambing in late August, with weaning on November 19. Normal shearing occurs December 15.

Three livestock systems are possible (Table 4.2.4.1):

1. All wether weaners are sold 1 month after weaning (~4 months old), remaining ewe weaners (hoggets, less those kept as replacements) sold prior to weaning of the next cohort of lambs (~ 15 months old).
2. All wether and remaining ewe weaners (hoggets, less those kept as replacements) are sold prior to weaning of the next cohort of lambs (~15 months old).
3. A wether flock is maintained up to 4 years old. Remaining wether weaners (less those kept as replacements) are sold 1 month after weaning (~4 months old), remaining ewe weaners (hoggets, less those kept as replacements) sold prior to weaning of the next cohort of lambs (~ 15 months old).

Table 4.2.4.1. Stocking rates were set to maintain the same average DSE for each system.

Livestock system	Ewes per ha	Wethers per ha
1	8.5	0
2	6.3	0
3	5.3	3

Long-term (1900-2019) annual average rain was 652 mm

Grazing management

Initially the "best paddock" (most available feed) was selected every 7 days, and weaned lambs were placed in this paddock, while the ewes went into this paddock after 7 days ("follow paddock"). However, problems with ewe conception rates and over supplementary feeding of wethers in livestock system 3, required a rethink.

4.2.4.1 Livestock system 1 (wethers sold at 4 months)

Paddock allocation is described in Table 4.2.4.1.1, paddocks 1 to 3 were allocated to weaned lambs and replacement ewe hoggets (W paddocks), while paddocks 4 to 10 were allocated to the ewes (E paddocks).

Table 4.2.4.1.1. Paddock allocation for livestock system 1

Period	Ewes	Weaners	Ewe Hoggets	Dry ewes after scanning (in managed model)	Comments
Jan 1 to Feb 14	Best E	Best W	Best W	Best E	Post weaning
Feb 15 to Mar 31	Best E	Best W	Best W	Best E	Flushing
Apr 1 to Jun 27	Best E	Best W	Best W	Best E	Joining to scanning
Jun 28 to Nov 17	Best E	Best W	Best W	2nd Follow E	Scanning to weaning
Nov 18 to Dec 31	Best E	Best W	Best W	Best E	Post weaning

4.2.4.2 Livestock system 2 (wethers sold at 15 months)

Paddock allocation is the same as for Livestock system 1.

4.2.4.3 Livestock system 3 (wethers sold at 4 years)

Paddock allocation is described in the following table (Table 4.2.4.3.1), paddocks 1 to 6 were allocated to ewes and lambs ("E" paddocks), while paddocks 7 to 10 were allocated predominately to wethers ("W" paddocks), except for ewes after weaning and dry ewes post scanning.

Table 4.2.4.3.1. Paddock allocation for livestock system 3

Period	Ewes	Weaners/ Hoggets	Ewe Replacements	Dry ewes after scanning (in managed model)	Wethers	Wether Replacements	Comments
Jan 1 to Feb 14	Follow E	Best E	Best E	Follow E	2nd Follow W	Best W	Post weaning
Feb 15 to Mar 31	Best E	2nd Follow E	2nd Follow E	Best E	Follow W	Best W	Flushing
Apr 1 to Jun 27	Best E	2nd Follow E	2nd Follow E	Best E	Follow W	Best W	Joining to scanning
Jun 28 to Nov 17	Best E	2nd Follow E	2nd Follow E	Follow W	2nd Follow W	Best W	Scanning to weaning
Nov 18 to Dec 31	Follow W	Best E	Best E	Follow W	2nd Follow W	Best W	Post weaning

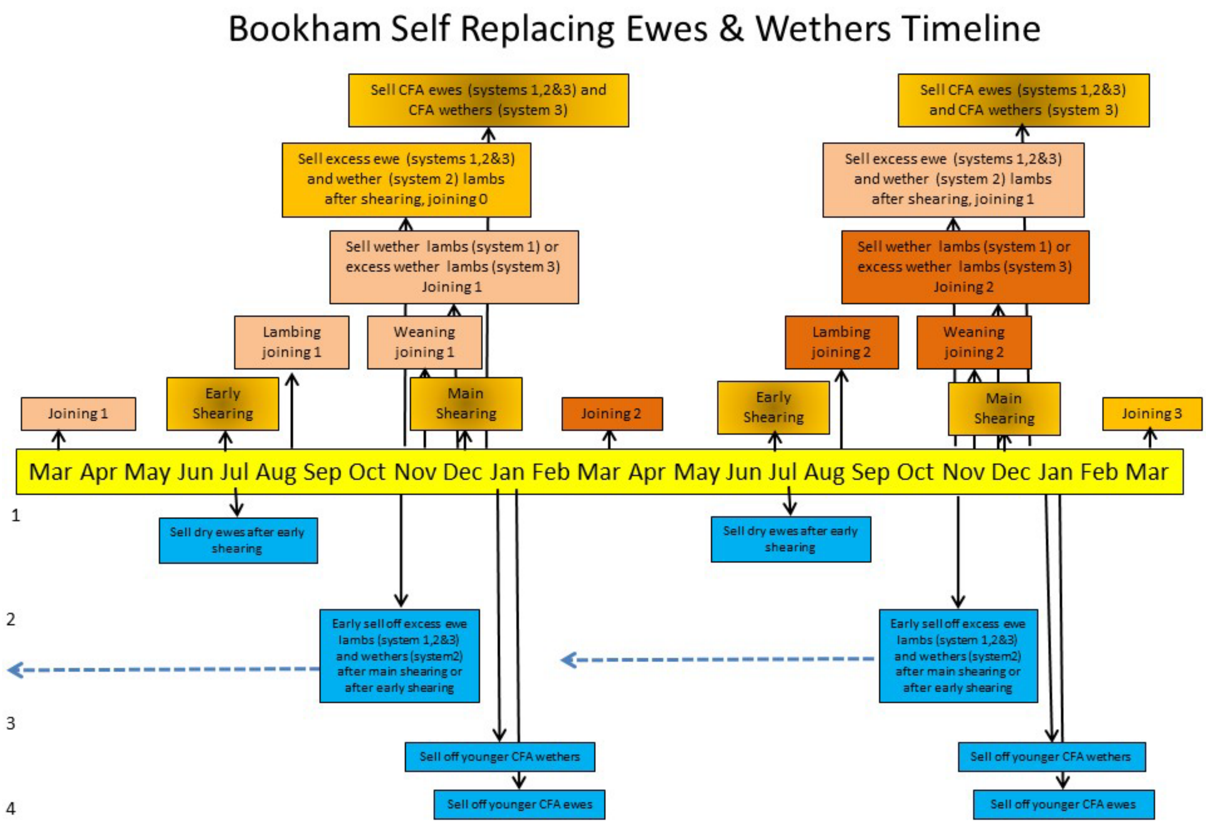


Figure 4.2.4.1. Decision timeline over two years for Bookham sheep production incorporating all 3 livestock systems. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour.

Below the yellow shaded month bar are management activities in response to trigger points. The blue dashed horizontal arrows below the yellow shaded month bar indicates change in sale times in response to trigger points.

NOTE Option 5 – Don't join maiden ewes (run as wethers) as they were not included in the current simulations.

Decision protocols for flexible decisions (Livestock system 1):

1. Sell off non-pregnant ewes after early shearing. Ewes are scanned June 27, empty ewes that are older than 2 years are shorn July 10 (6 months wool) and sold July 17.
2. Early sell-off of ewe lambs (hoggets) after early shearing (July 10), sold July 18 if total green biomass in W paddocks at July 1 is < 133 000 kg. Otherwise, normal sell-off occurs on 18 November, after weaner shearing 13 November.
3. Sell-off of younger CFA ewes. Total green biomass on March 1 and average %soil moisture for the first 2 months are determined. If total green biomass in E paddocks is less than 266 000 kg and relative soil moisture averages less than 40% on March 1, the next oldest cohort of ewes are sold 7 March (usually 5 years but can be 4 years if a run of poor years occurs).
4. Decision protocols for flexible decisions (Livestock system 3): Sell off non-pregnant ewes after early shearing. Ewes are scanned June 27, empty ewes that are older than 2 years are shorn July 10 (6 months wool) and sold July 17.
5. Early sell-off of ewe lambs (hoggets) after early shearing (July 10), sold July 18 if total green biomass at July 1 is < 400 000 kg. Otherwise, normal sell-off occurs on 18 November, after weaner shearing 13 November.
6. Sell-off of younger CFA wethers. Total green biomass on March 1 and average %soil moisture for the first 2 months are determined. If Total green biomass in the W paddocks is less than 166 000 kg, and relative soil moisture averages less than 40%, the next oldest cohort of wethers are sold 7 March (older than 2 or 3 years).
7. Sell-off of younger CFA ewes. Total green biomass on March 1 and average %soil moisture for the first 2 months are determined. If Total green biomass in the E paddocks is less than 234 000 kg, and relative soil moisture averages less than 40%, the next oldest cohort of ewes are sold 7 March.

Management Decisions Livestock system 2.

As there were minimal differences between the contrasting livestock systems 1 and 3 for pasture production and soil moisture, it was assumed that Livestock system 2 would also be similar to livestock system 1. Because of this, similar management decisions based on green biomass were developed.

Decision protocols for flexible decisions (Livestock system 2):

1. Sell off non-pregnant ewes after early shearing. Ewes are scanned June 27, empty ewes that are older than 2 years are shorn July 10 (6 months wool) and sold July 17.
2. Early sell-off of wether weaners on March 7 if total green biomass in W paddocks < 100 000 kg on March 1, otherwise normal sale occurs unless option 3 is met.
3. Early sell-off of ewe and wether weaners (hoggets) after early shearing (July 10), sold July 18 if total green biomass in W paddocks at July 1 is < 133 000 kg. Otherwise, normal sell-off occurs on 18 November, after weaner shearing 13 November.
4. Sell-off of younger CFA ewes. Total green biomass on March 1 and average %soil moisture for the first 2 months are determined. If total green biomass in E paddocks averages less than 266 000 kg and relative soil moisture averages less than 40% at March 1, the next

oldest cohort of ewes are sold 7 March (usually 5 years but can be 4 years if a run of poor years occurs).

4.2.5 GLENRAC

The producer focus group identified two systems for this region. The first was a cattle trading system and the second was a mixed self-replacing sheep and cattle system. The producers were interested in how the progressive selling compared to feeding on profitability and sustainability. The analysis looked at the ability of these systems to adapt to drought and compared flexible stocking decisions to a more rigid approach with higher levels of supplementary feeding.

As there were no existing models for this site, this model was developed based on information from the producer group. Farm comprises 640 ha split up into 18 paddocks – half of area as basalt soil (Gn 3.12), half trap soil (Dy 3.42). 10 paddocks of basalt soil (each 32 ha), comprising annual ryegrass, phalaris, fescue and cocksfoot. 8 paddocks of trap soil (each 40 ha), with 4 paddocks sown with annual ryegrass, phalaris, fescue and cocksfoot, with 4 paddocks comprising annual ryegrass, redgrass, danthonia and *Poa sieberiana*. Legumes were removed after consultation with industry expert. This farm was used for two models – Glenrac cattle and Glenrac mixed.

To determine fertility factors for the pastures, the base Glenrac cattle model was run at 1 steer per hectare with different fertility factors until all steers were sold at target weight for 75% of runs (82 out of 110 years).

Fertility and rooting depths in Table 4.2.5.1 were then used.

Table 4.2.5.1. Fertility and root depth of the basalt and trap soils.

Soil Type	Pasture type	Pasture	Fertility factor	Rooting depth (mm)
Basalt	Sown	Annual ryegrass	0.5	300
		Phalaris	0.7	855
		Fescue	0.7	855
		Cocksfoot	0.7	855
Trap	Sown	Annual ryegrass	0.5	300
		Phalaris	0.7	700
		Fescue	0.7	700
		Cocksfoot	0.7	700
Trap	Native	Annual ryegrass	0.5	300
		Redgrass	0.6	700
		Danthonia	0.7	700
		Poa	0.6	700

Long-term (1900-2019) annual mean rain was 853 mm. Severe rainfall deficit (< 50% mean has occurred only in 2019.

4.2.5.1 Glenrac Cattle

Cattle trading system based on Angus steers purchased at 320 kg and sold at 480 kg. Cattle purchased on July 30 (50% of purchase), August 30 (25% of purchase) and September 30 (25% of purchase). Cattle sold from November 30 when target weight of 480 kg is met or sold by July 29.

Cattle are moved every 4 days to the paddock with the best available green feed.

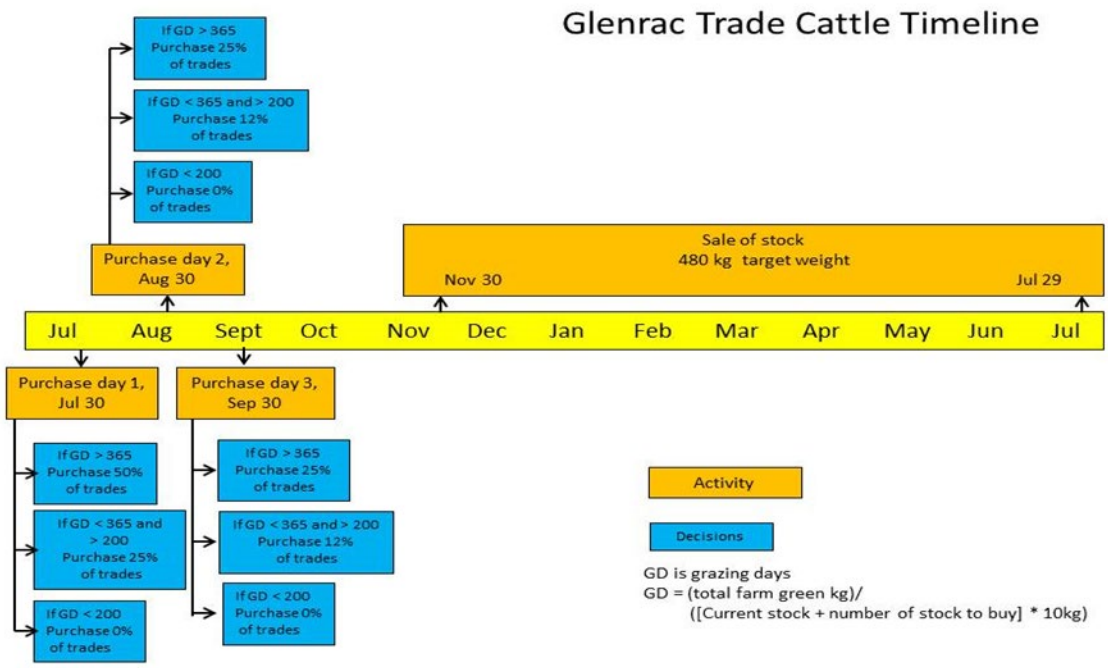


Figure 4.2.4.1. Yearly decision timeline for Glenrac trade cattle production. Normal livestock activities (purchase and sale) are shown in orange shaded boxes, on either side of the yellow shaded month bar. The blue shaded boxes show purchase decisions based on Grazing Days.

Management decisions were made at purchase times, based on the total kg of farm green biomass divided by stock number feed requirement to determine the number of grazing days available (GD). The stock number feed requirement is the number of stock (on hand plus number to be purchased) multiplied by a daily feed requirement (10 kg). At each purchase time, if GD > 365, the full number of trade cattle are purchased. If GD < 365 but > 200, half the number of trade cattle are purchased. If GD < 200, no purchases are made.

4.2.5.2 Glenrac Mixed

Self-replacing cattle and sheep enterprises. Cattle enterprise runs on basalt soils and sheep enterprise runs on trap soils. Paddock allocation occurs every 7 days and is described in the following table (Table 4.2.5.2.1).

Table 4.2.5.2.1. Sheep and cattle enterprises run on different soil types.

Sheep enterprise	Trap soil paddock	Cattle Enterprise	Basalt soil paddock
Weaned lambs	Best	Weaners	Best
Replacement ewes	2nd Follow	Replacement and maidens	2nd Follow
Wethers	3rd Follow	Dry cows	1st Follow
Ewes	1st Follow	Cows	1st Follow

Cattle

Cattle system based on Angus cows and calves at a stocking rate of 0.3 cows/ha of farm area (192 cows). Joining starts on October 1, for 60 days, to calve in July. Weaning was at 8 months (March). Weaned steers were sold on April 15, while excess weaned heifers not used as replacements, were sold February 15 (prior to weaning of the next cohort of calves). CFA cows sold at 10 years old on April 15.

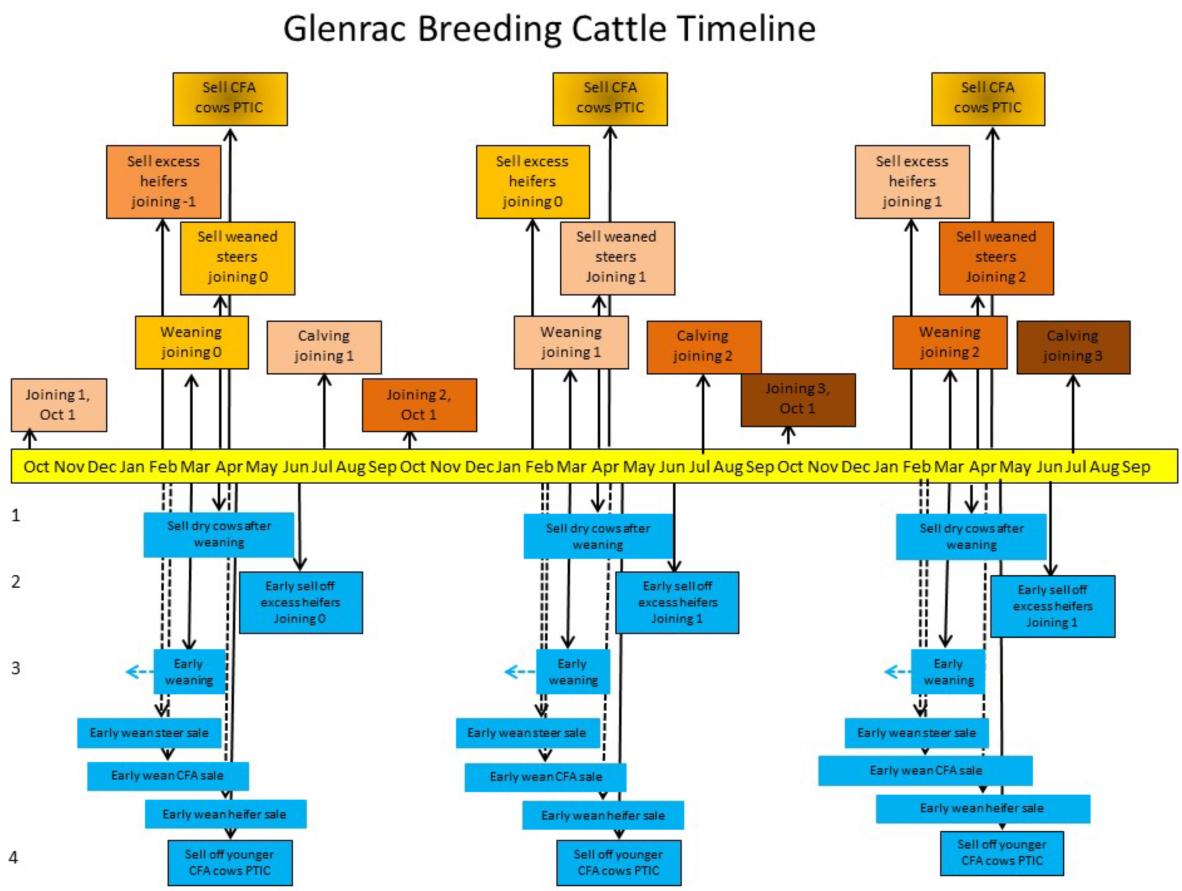


Figure 4.2.5.2.1. Decision timeline over three years for Glenrac breeding cattle production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points. The blue dashed horizontal arrows below the yellow shaded month bar indicate change in weaning times in response to trigger points, while the black dashed vertical lines indicate the subsequent change in sale times due to early weaning.

Decision protocols for flexible decisions:

1. Sell dry cows after weaning. Cows are scanned halfway through gestation and cows older than 2 years old are sold after weaning. Note that the Dry Cow value is less than CFA cows which are PTIC.
2. Early sell-off of excess heifers. Total green biomass on basalt soil is determined on May 15. to determine May_graze_days. If May_graze_days < 50, heifers are sold early on June 15, otherwise normal sale on February 15
3. Early weaning. On November 15, if total green biomass on the basalt soil is less than 1875 kg/ha, then early weaning occurs in January, otherwise weaning occurs at the normal time of March.
   iii. If early weaning occurs, weaner steers are sold on February 16.
   iv. If early weaning occurs, early sale of excess heifers can occur. Total green biomass on basalt soil is determined on March 15, and March_graze_days is determined as described previously. If March_graze_days <50, then heifers are sold on April 15, otherwise normal sale on February 15.

v. If early weaning occurs early sale of CFA cows occurs on February 16. These cows are PTIC, as compared to dry cows sold in decision 1.

4. Sell younger CFA cows, PTIC. With normal weaning in March, total green biomass on basalt soil is determined on April 15, and April_graze_days is determined as described previously. If April_graze_days is >20, normal CFA age of 10 years is used on April 16. If >5 and < 20, CFA of 9 years, and if <5, CFA of 8 years is used on May 15.

With early weaning in January, total green biomass on basalt soil is determined on February 15, and February_graze_days is determined as described previously. If February_graze_days is >30, normal CFA age of 10 years is used on February 16. If >10 and < 30, CFA of 9 years, and if <10, CFA of 8 years is used on March 15.

Notes - The determination of critical values for Month_graze_days, was determined by looking at actual monthly graze_days from 1910 to 2019 using the true weather and reviewing the years when low graze_days occurred.

Sheep

The sheep system is a self-replacing merino flock (stocking rate of with 2.5 ewes/ha of farm area – 1600 ewes) and a wether proportion (1.5 wethers/ha of farm area – 960 wethers). Joining is in April to lamb in September. Weaning occurs in January, with excess wether lambs sold in February. CFA ewes, older than 6 years, are sold after weaning, while CFA wethers, older than 4 years, are sold after shearing in July. Excess ewe lambs are sold prior to weaning.

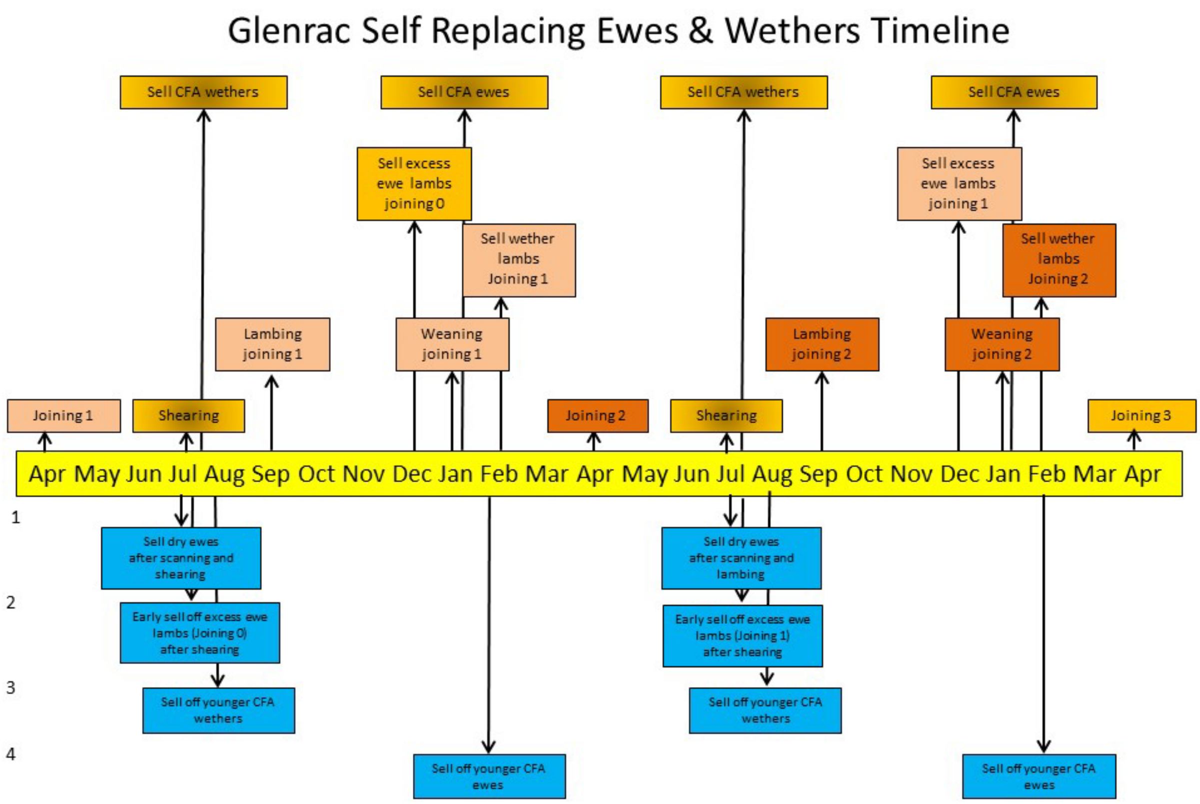


Figure 4.2.4.1. Decision timeline over two years for Glenrac sheep production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth,

weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points

Decision protocols for flexible decisions:

1. Sell dry ewes after scanning and shearing. Scan ewes mid gestation for nil foetuses, all dry ewes (older than 2 years) are sold.
2. Early sell-off of weaner ewe lambs. Total green biomass available of Trap soils is calculated July 15 (July green). If July green > 900 kg/ha, normal sell-off occurs in December. If July green < 300 000 kg, weaner ewe lambs are sold after shearing on August 1.
3. Sell younger CFA wethers. If July green < 1600 kg/ha, then the next oldest cohort of wethers are sold on August 15.
4. Sell younger CFA ewes. Total green biomass available of Trap soils is calculated January 15 (January green). If January green < 1250 kg/ha, then the next oldest cohort of ewes are sold on February 15.
5. Don't join maiden ewes not included in this model.

4.2.6 Central West Farming Systems

There was a large diversity in the geographic range and farming system in the Central West Farming Systems focus group, with mixed farming to the east and areas of rangeland to the west of Condobolin. A decision was made to focus on self-replacing sheep and beef systems at the geographic centre of the region. The flexible management of livestock systems to adjust stocking rate compared to rigid system and the amount of grain needed to be retained for supplementary feeding were the main focus of the group. Practically producers had put crops into bunkers as grain or silage in preparation for drought.

This model was developed from the Condobolin validation AusFarm model (Cashen *et al* 2015). The 4000-ha farm was split into sixteen 250 ha paddocks using APSoil #690, 8 paddocks in a cropping rotation with lucerne (Crop1 to Crop8), 6 paddocks in an oats:lucerne rotation (Oats1 to Oats6), and 2 paddocks of native pasture (Native1 and Native2). The Crop rotation comprised fallow (F), wheat (W), barley (B) and Lucerne (L) as $FWWBW_{undersownL}LLL$, the Oats rotation comprised oats (O) and lucerne (L) as $OOO_{undersownL}LLL$, while the native pasture comprised *Austrostipa* spp, annual ryegrass and subclover (Dalkeith). Lucerne in rotations was sown with subclover (Dalkeith) and medic (Parragio).

Long-term (1900-2019) average yearly rain was 423 mm

Two livestock systems were modelled – self-replacing merino, and self-replacing cattle selling feeder steers at 440 kg and heifers at 210 kg. The sheep model was run on the cropping rotation paddocks, whilst the cattle model was run on the oats rotation and native paddocks.

4.2.6.1 Merino ewe livestock system

From the producers present at the initial consultation, a representative livestock system was developed. Self-replacing medium merino ewes were joined in March to lamb in August with weaning in November. Wether offspring were sold at 12 months, with excess ewe offspring (not used as replacements) sold in November prior to the weaning of the next cohort of lambs.

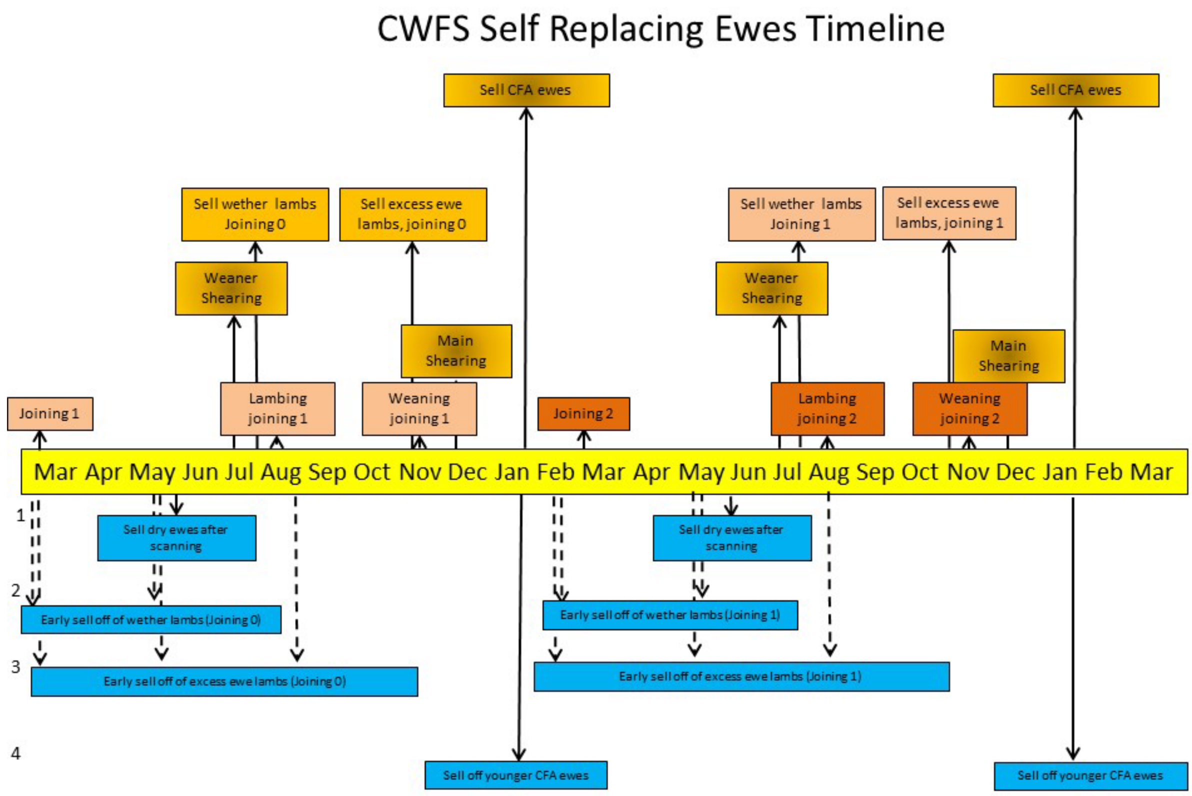


Figure 4.2.6.1.1. Decision timeline over two years for CWFS sheep production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points, while the black dashed vertical lines indicate the subsequent change in sale times.

4.2.6.2 Development of trigger points

The basic model was run for 110 years. Total green pasture production (lucerne, subclover and medic from the cropping rotations, was determined on the 15th of each month for the farm. Total green pasture was divided by the anticipated ewe number (ewe stocking rate * farm area) multiplied by 2, as the offspring was normally kept for at least 1 year, to determine the monthly ewe trigger. The relationships between these triggers and management activities were investigated to determine trigger points.

Decision protocols for flexible decisions:

1. Sell dry ewes after scanning. Ewes are scanned mid-gestation, and dry ewes older than 2 years are sold two weeks after scanning.
2. Early sale of wether lambs. Normal sale is August 1, prior to lambing of the next cohort of lambs. If January trigger < 50, sell wether lambs on February 15. If April trigger < 75, sell wether lambs on May 15
3. Early sale of ewe lambs. Normal sale is November 1, prior to weaning of the next cohort of lambs. If January trigger < 50, sell ewe lambs on February 15. If April trigger < 75, sell ewe lambs on May 15. If July trigger < 75, sell ewe lambs on August 15
4. Sell younger CFA ewes. If January trigger < 50 younger CFA ewes are sold on January 31.

4.2.6.3 Feeder steer livestock system

From the producers present at the initial consultation, a representative livestock system was developed. Self-replacing Hereford cattle were selected, joined in October, calving in July, and weaned at 6 months in January. Excess heifers were sold at 9 months (at approximately 210 kg), while feeder steers were sold at 440 kg, up to 20 months old. Feeder steers were supplementary fed to obtain the target weight.

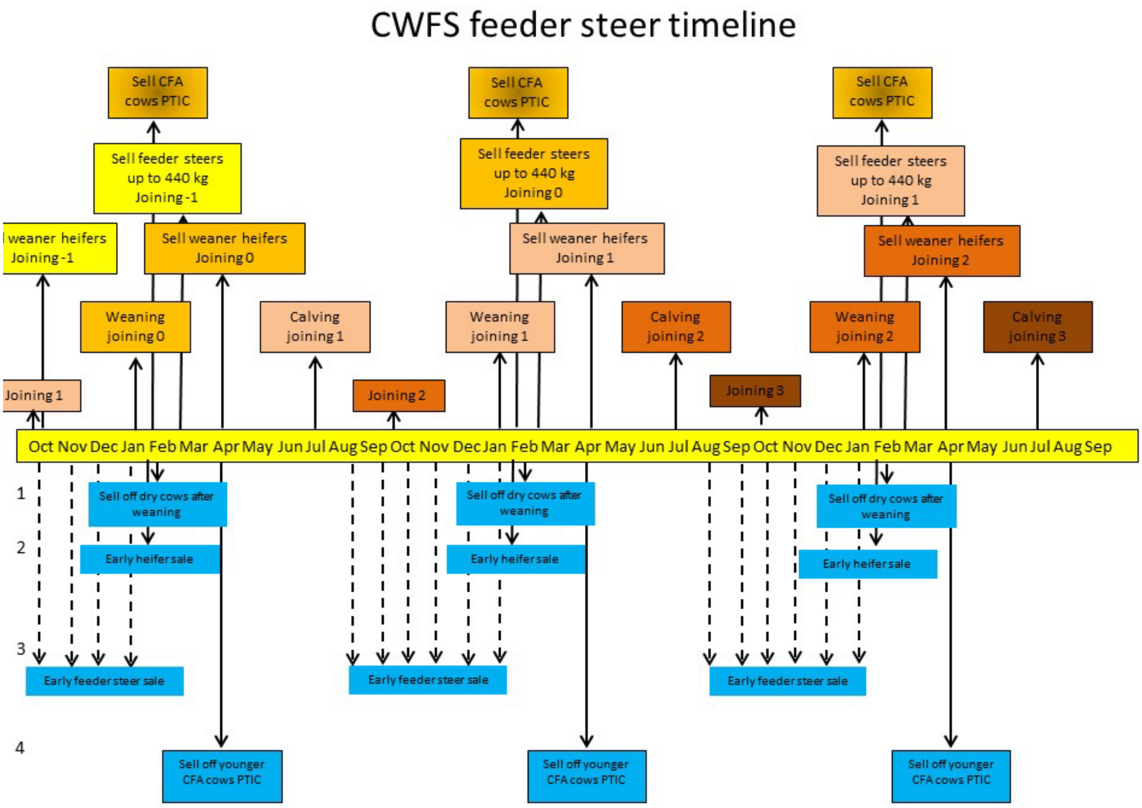


Figure 4.2.6.2.1. Decision timeline over three years for CWFS feeder steer production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points, while the black dashed vertical lines indicate the subsequent change in sale times.

4.2.6.4 Development of trigger points

The basic model was run for 110 years. Total green pasture production (lucerne, subclover and medic from the oats rotations, *Austrostipa*, annual ryegrass and subclover from the native pastures) was determined on the 15th of each month for the farm. Total green pasture was divided by the anticipated cow number (cow stocking rate * farm area) multiplied by 10 (approximate daily kg green intake per cow) multiplied by 3 (offspring and feeder steers), to determine the monthly cow trigger. The relationships between these triggers and management activities were investigated to determine trigger points. Note that as weaning was already occurring at 6 months, it was decided not to include an early weaning.

Decision protocols for flexible decisions:

1. Sell dry cows after weaning

2. Early sale of heifer weaners. When the January trigger was < 75, weaner heifers are sold on February 1. Normal sale is April 1.
3. Early sale of feeder steers. There was a good correlation in monthly triggers and supplementary feeding to reach the target weight of 440 kg. When the August trigger was < 150, steers were sold on August 20 (with the true weather file this occurred 14 times, with only 1 year not having substantial supplementary feeding). When the September trigger was < 175, steers were sold on September 20 (this occurred once). When the December trigger was < 175, steers were sold December 20 (twice). When the January trigger was < 100, steers were sold on January 20 (this occurred 27 times, with 12 years not having substantial supplementary feeding). Normal sale of feeder steers was from October 1 to March 1.
4. Sell younger CFA cows PTIC. If the March trigger was < 85, younger cows were sold on April 1

4.2.7 Singleton and Dungog Gresford beef groups

The producer focus group identified cattle production for the vealer trade as the main enterprise. The amount of grain needed for supplementary feeding and the cost of that grain was a key focus and this was to be compared to systems where greater levels of destocking.

As there were no existing models for Tocal, this model was developed based on information from the producer group. Farm area was 220 ha split into 20 paddocks. The farm was split up into 20% Flats (14 * 3ha paddocks, soil type Um6.11), 50% Ridge (4 * 28ha paddocks, soil type Dy3.41) and 30% Hill (2 * 33ha paddocks, soil type Um6.11 – shallow). Pasture species were annual ryegrass, subclover (Seaton Park), and kikuyu for Flats and Ridge, and *Austrostipa* spp, *Bothriochloa*, and annual ryegrass for Hill. While irrigation is available, discussions with the producer group ruled it out due to the excessive costs of pumping.

The livestock system is butcher vealers with buy in Angus cows, joined to Limousin bulls. Usually, joining is split up monthly to provide a constant supply of vealers throughout the year. To simplify modelling, 2 joinings occur, with the cattle herd is split into two separate cohorts with cohort 1(Mob 1) joined in October and cohort 2(Mob 2) joined in May. Because of this splitting into two distinct herds, the farm is split into 2 sub farms each comprising 7 Flats paddocks, 2 Ridge paddocks, and 1 Hill paddock. Sale of vealers occurs at weaning, straight off cows to meet MSA (Meat Standards Australia) standards.

Long-term (1900-2019) average yearly rain is 956 mm.

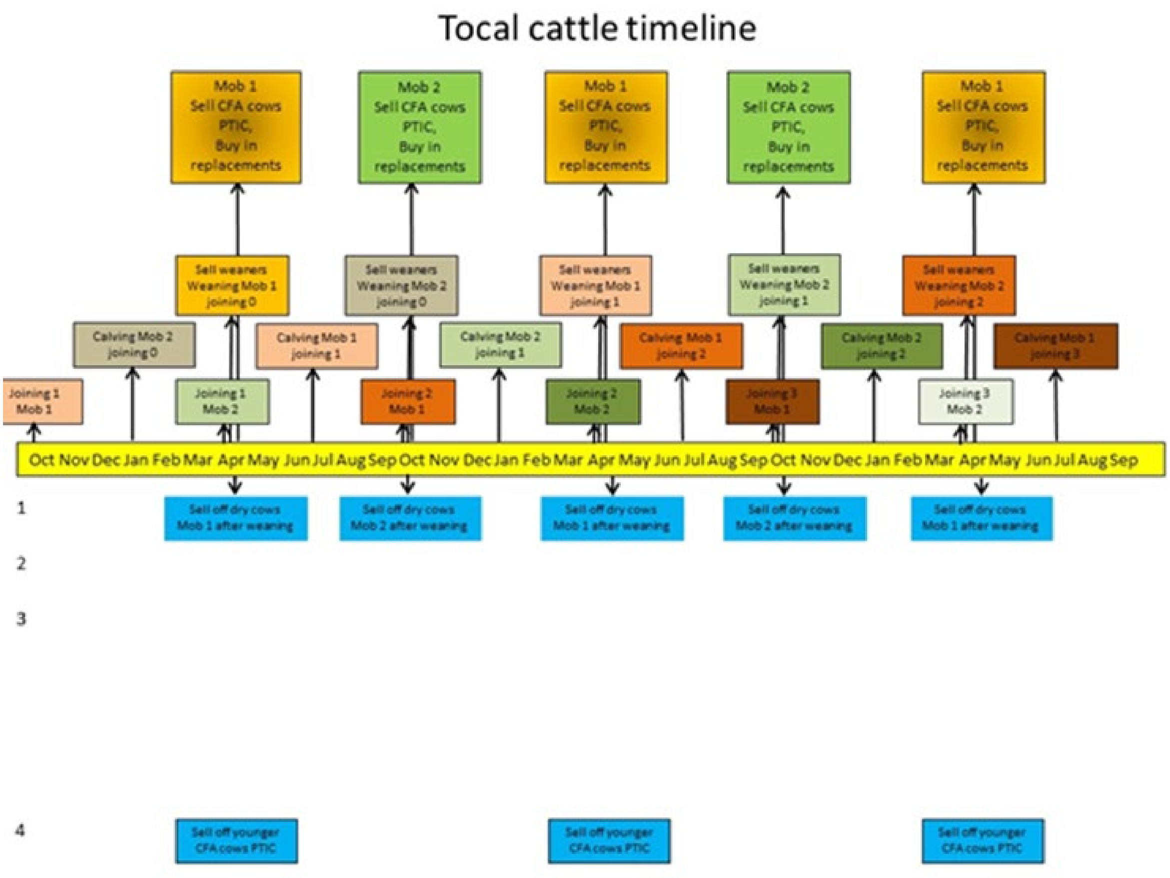


Figure 4.2.7.1. Decision timeline over three years for Tocal production. Normal livestock activities are shown above the yellow shaded month bar, with each joining and subsequent birth, weaning and sale of offspring cohort shaded in the same colour. Below the yellow shaded month bar are management activities in response to trigger points.

4.3 Whole-farm economic analysis

Whole-farm economic analysis results are presented below for all sites, except the Central West Farming Systems and the Singleton and Dungog Gresford beef groups, which were still being finalised at the time the report was submitted. The analyses from rangelands sites are reported separately.

4.3.1 Orange EverGraze Regional Group (Panaura)

4.3.1.1 Sheep

The managed sheep system at Orange has a higher average gross margin of $304/ha compared to the baseline average of $271/ha (Figure 4.3.1.1.1). The baseline system also has higher variability in returns, with a standard deviation of +$157/ha compared to +$139/ha for the managed system. The Managed scenario was able to mitigate losses in poor seasons with a smaller deficit in poor years, while maintaining exposure to higher profit in good seasons. When combined, this suggests that the Managed scenario optimises average returns while minimising exposure to excessive variability in returns and downside risk.

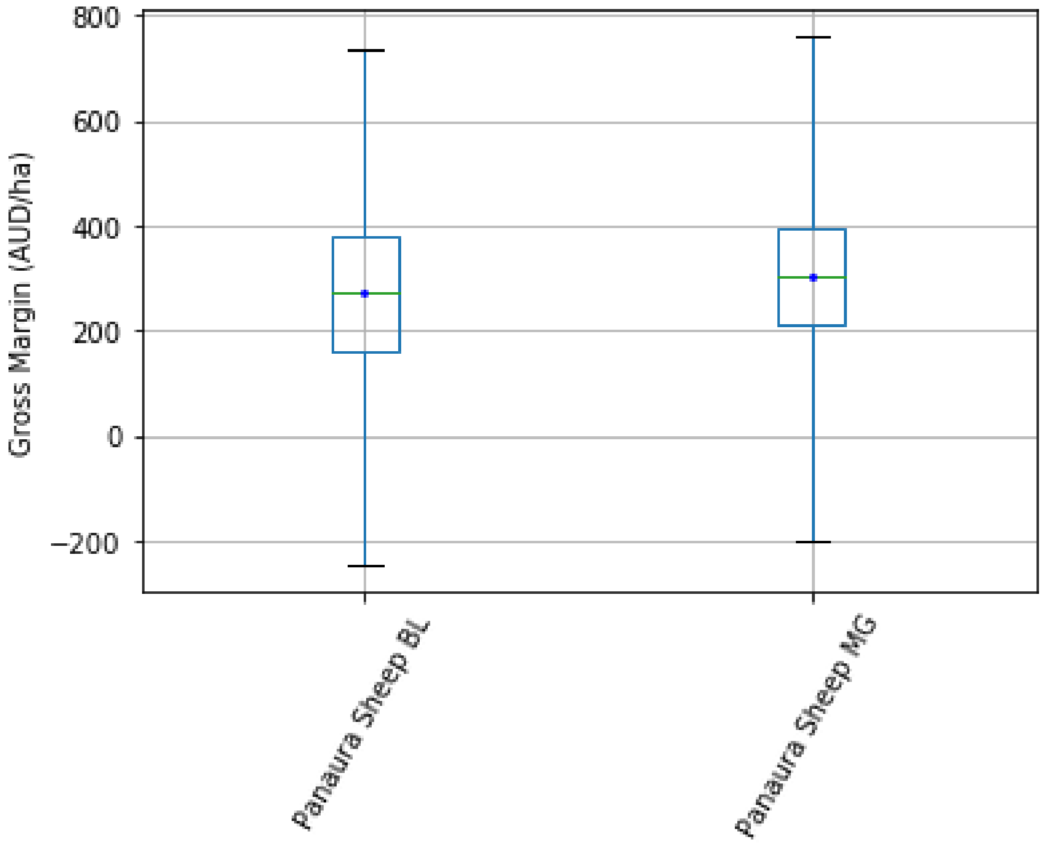


Figure 4.3.1.1.1: Box and whisker plots indicating the mean (circle), median (vertical line within box plot), maximum and minimum GM/ha return for the Panuara Sheep system Baseline (BL) and Managed (MG) Scenarios.

4.3.1.2 Cattle

The baseline system outperforms the managed system on average, with mean gross margins of $126/ha and $117/ha, respectively (Figure 4.3.1.2.1). This was associated with greater variability in returns, with a standard deviation of ±$85/ha for the baseline compared to ±$72/ha for the managed system. While the baseline had higher returns in good seasons, this was associated with downside risk in poor seasons, with a range between -$219 and $438 compared to -$132 and $393 for the managed system (Figure 4.3.1.2.1). While the baseline system increased average gross margins by $8.5%, it also increased variability and downside risk, and as a result may not be a preferred option for producers with a low risk appetite.

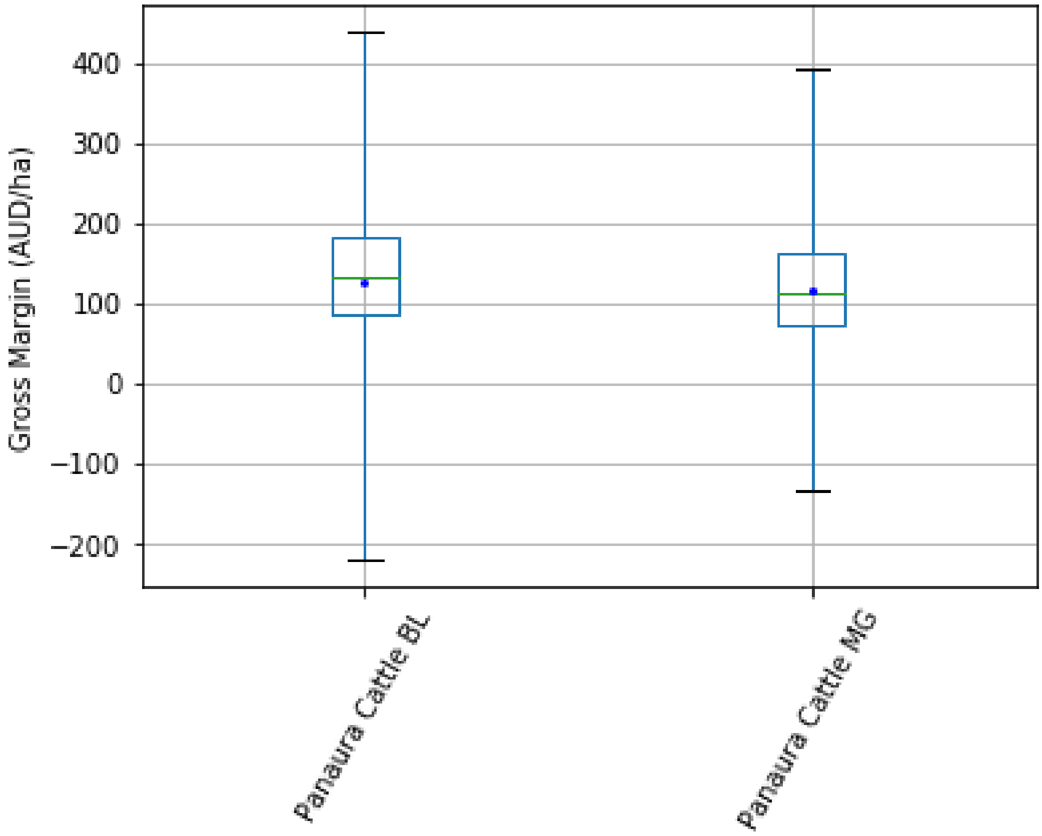


Figure 4.3.1.2.1: Box and whisker plots indicating the mean standard deviation (circle), median (vertical line within box), maximum and minimum GM/ha return for the Panura Cattle Baseline (BL) and Managed (MG) scenarios.

4.3.2 Monaro Farming Systems

4.3.2.1 Bungarby

The average profitability of the baseline system is marginally higher than that of the managed system, however this is also associated with variability and downside risk. The average gross margin was $263/ha and $257/ha for the baseline and managed, respectively. While the baseline scenario had a 2.5% higher average return, this was associated with a 21% increase in the variability with a standard deviation of ±$113/ha compared to ±$93/ha for the managed scenario (Figure 4.3.2.1.1). The baseline system had a higher maximum profit of $706/ha compared to $648/ha for the managed, and a lower minimum return of $8/ha compared to $26 in the managed system. While the baseline system was on average slightly more profitable, the trade-off with increased variability and downside risk may make it a less appealing option, particularly when the long-term impact of compounding debt is considered.

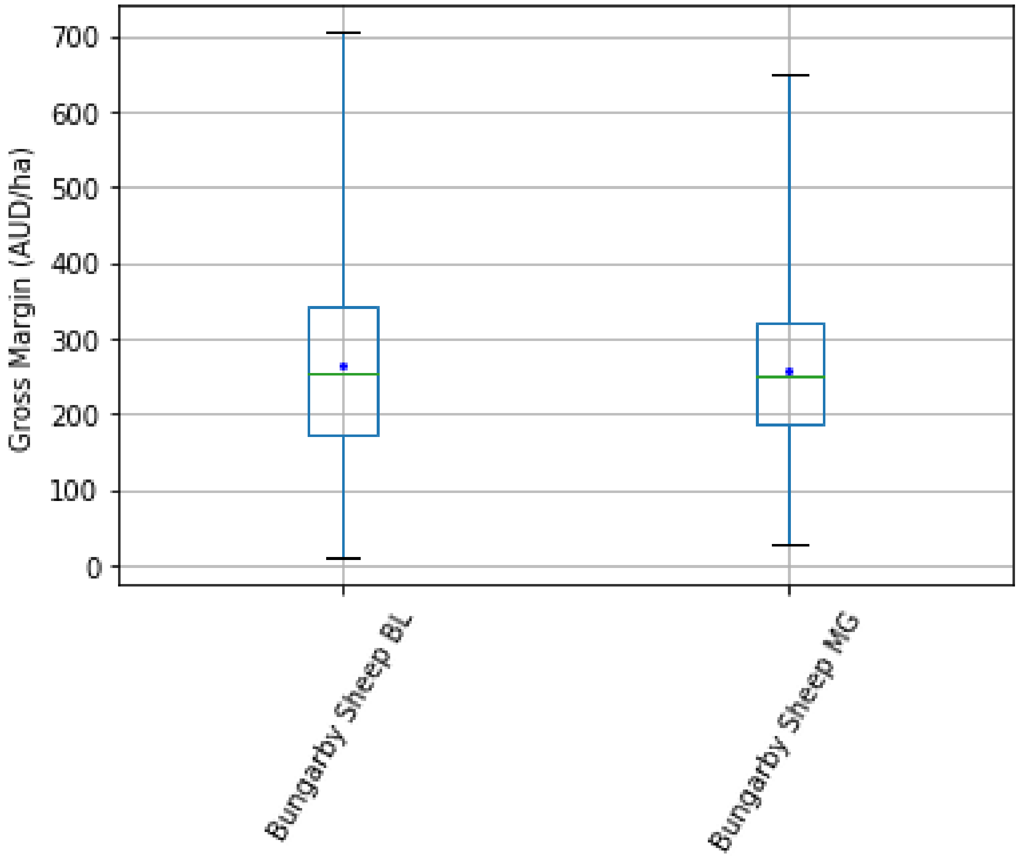


Figure 4.3.2.1.1: Box and whisker plots indicating the mean standard deviation (circle), median (vertical line within box), maximum and minimum GM/ha return for the Bungarby Baseline (BL) and Managed (MG) Scenarios.

4.3.2.2 Delegate

Result for the Delegate site had a similar pattern to those at Bungarby. Delegate system had a higher average gross margin for the baseline system, at $481/ha compared to $455/ha for the managed system (Figure 4.3.2.2.1). The baseline system returns were also more variable with a standard deviation of +$181/ha compared to +$141/ha in the managed system. While the baseline system had higher upside profits in good years with a maximum return of $1,006/ha compared to $903/ha in the managed system, this was also associated with a larger downside risk, the lowest annual return of $69/ha compared to -$155/ha in the managed system (Figure 4.3.2.2.1). As with the Bungarby site, there is a trade-off between the average profitability of the scenario and the associated higher level of variability and downside risk. Those operations with a strong balance sheet may be willing to take a higher level of risk for the potential of a 6% increase in profit.

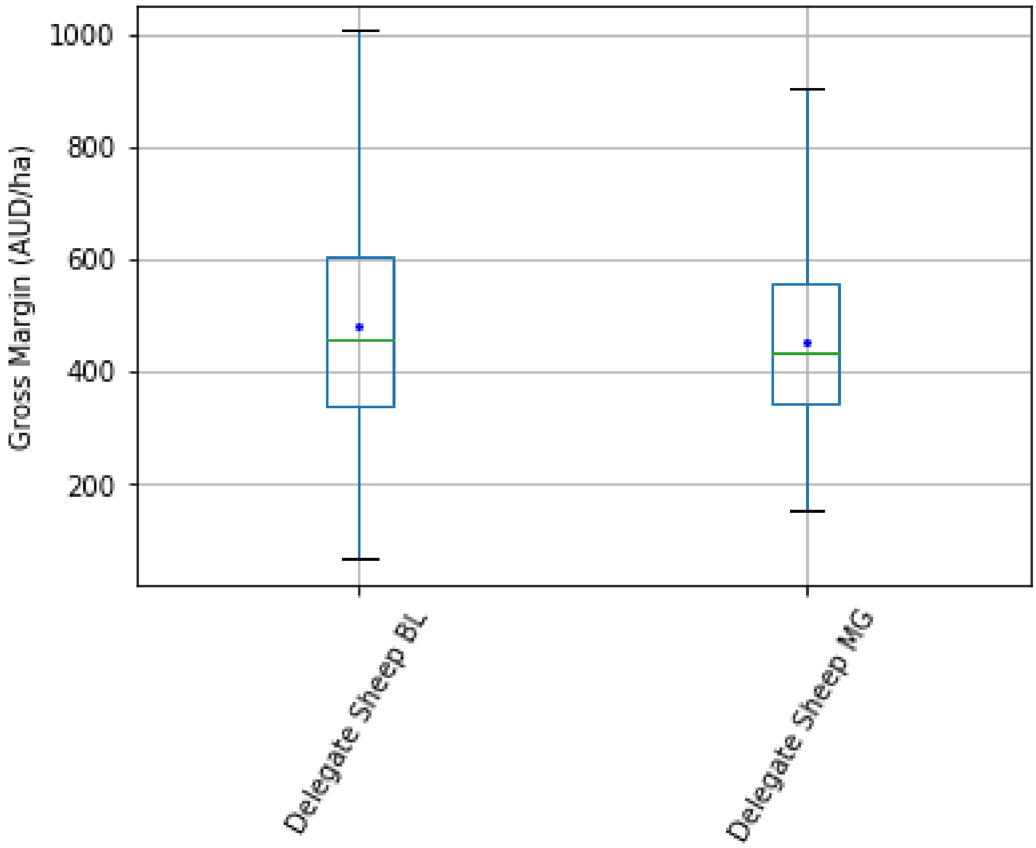


Figure 4.3.2.2.1: Box and whisker plots indicating the mean standard deviation (circle), median (vertical line within box), maximum and minimum GM/ha return for the Delegate Baseline (BL) and Managed (GM) Scenarios.

4.3.3 Bookham Ag Bureau

Among the Bookham treatments 15-month systems performed better that the 4-month and 4-year system (Figure 4.3.3.1). While the 15-month system had the highest profitability as measured by the average gross margin (GM), it also resulted in more risk (higher standard deviation). Across all systems the managed system reduced GM variability and downside risk.

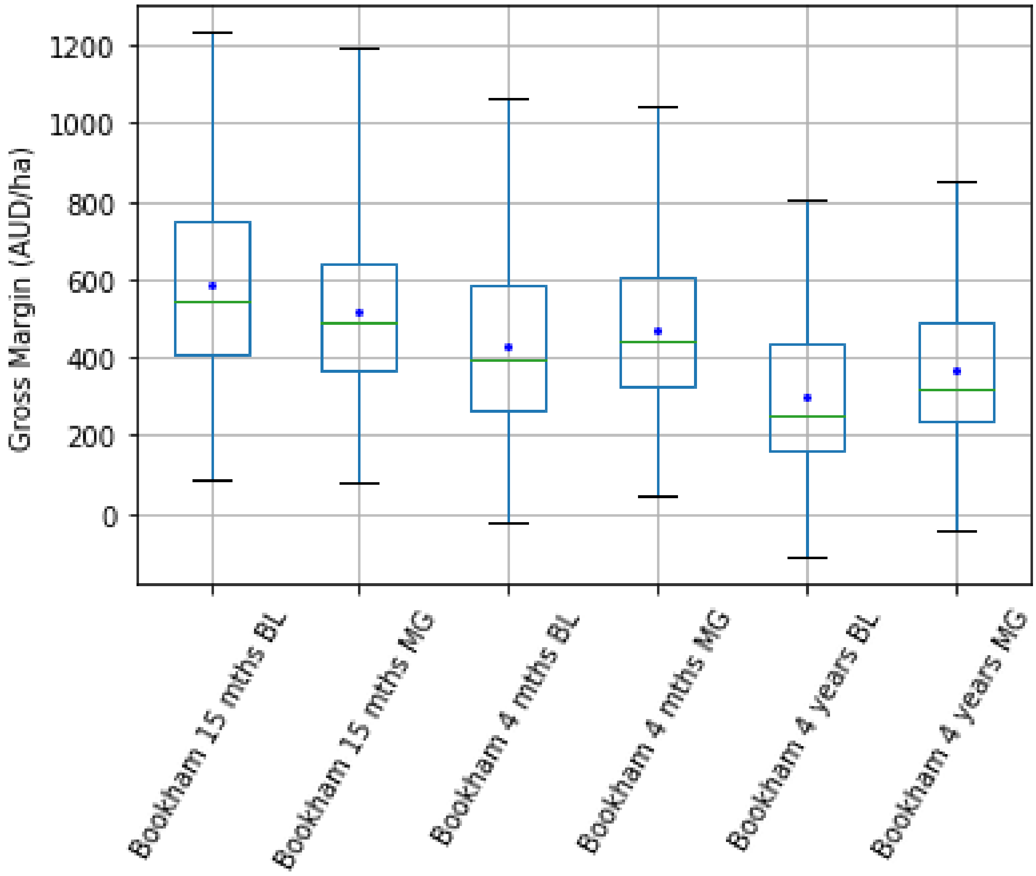


Figure 4.3.31.1: Box and whisker plots indicating the mean standard deviation (circle), median (vertical line within box), maximum and minimum GM/ha return for the three Bookham Baseline (BL) and Managed (MG) Scenarios.

4.3.3.1 4-*month* system

The average gross margin was higher in the managed scenario in the 4-month system, with an average return of $468/ha profit compared to $429/ha for the baseline (Figure 4.3.1.1). The managed system also had lower variability with a standard deviation of ±$186 compared to ±$212 in the baseline. The managed scenario reduced downside risk within the system, with a minimum return of $45/ha, while the lowest return in the baseline scenario was a -$25/ha deficit. The maximum return on both scenarios was similar at $1,065 and $1,044 respectively for the managed and baseline. The managed scenario in the 4-month system was able to increase average profitability and reduce risk, in term of both variability and downside risk.

4.3.3.2 15-month system

The average gross margins for the baseline and managed systems were $585/ha and $514/ha, respectively. While average profitability is higher in a baseline management scenario (Figure 4.3.3.1), the standard deviation for the managed system is lower at ±$291/ha, compared to the higher ±$343/ha for the baseline system. While the minimum return for the baseline and managed systems were similar, the maximum return was $140/ha higher in the baseline at $1238/ha. This suggests that the 15-month baseline system was able to minimise downside risk in poor years, while also capturing the upside potential in good seasons.

4.3.3.3 4-year system

The 4-year system was the worst performer out of the three Bookham systems, with the lowest average returns and largest downside risk (lowest returns in poor years). The managed scenario increase profitability and reduced risk compared to the baseline with an average profit (+StDev) of $364 ($170) compared to $296 ($178) in the baseline system (Figure 4.3.1.1).

4.3.4 GLENRAC

4.3.4.1 Mixed sheep and cattle

The baseline system was more profitable, on average, than the managed scenario, represented by mean gross margins of $193/ha and $166/ha, respectively (Figure 4.3.4.1). The variability of returns for the two scenarios were approximately the same with a standard deviation of +$52/ha for both. The maximum gross margins were also similar, with the managed system being slightly more profitable at $324/ha compared to $313/ha in the baseline system. However, the downside risk of the baseline system was smaller, with a minimum gross margin of $50/ha compared to $22/ha in the managed system. The baseline system have a similar variability and risk profile as the managed system but outperforming on average returns, making it the optimal choice.

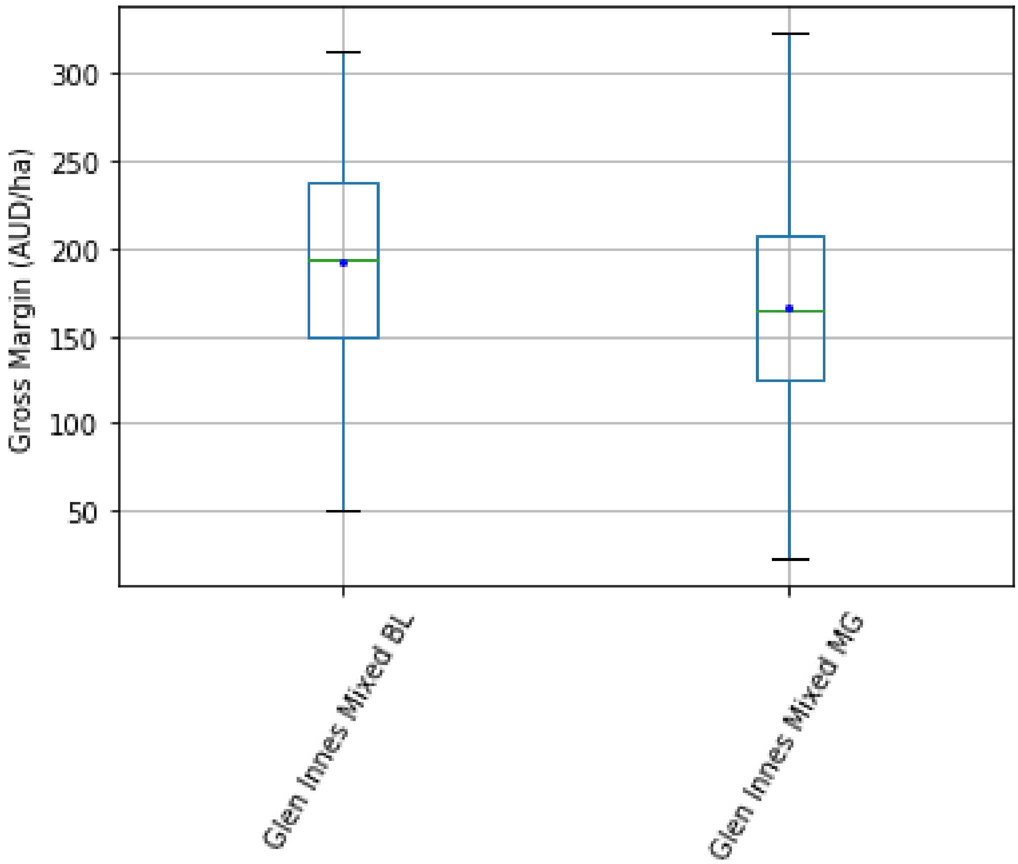
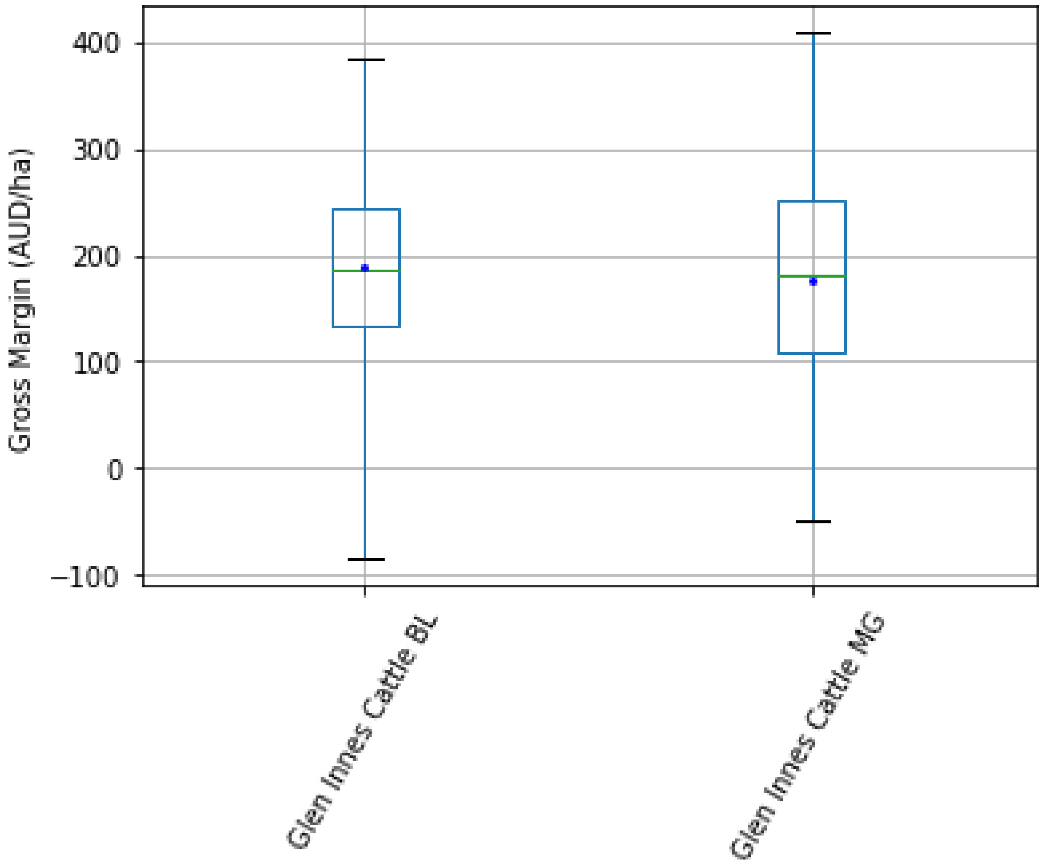


Figure 4.3.4.1.1: Box and whisker plots indicating the mean standard deviation (circle), median (vertical line within box), maximum and minimum GM/ha return for the Glen Innes Mixed Baseline (BL) and Managed (MG) scenarios.

4.3.4.2 Cattle trading

The baseline system displays higher average gross margins and lower risk than the managed system, driven by both the upside and downside risk in the system (4.3.4.2.1). The average gross margins were $190/ha and $177/ha and the standard deviations were ±$78/ha and ±$142/ha for the baseline and managed systems, respectively. With this in mind, supplementary feeding in both systems was very low, with on average just 1 tonne per annum feed in the managed system and 2 tonnes per annum for the baseline. These low numbers suggest the stocking rates for these systems may have been too low. The maximum and minimum gross margins for the baseline system were $385/ha and -$85/ha, whilst the managed system had a range of $409/ha and -$49/ha. While the managed system had higher variability, as measured by the standard deviation, it also had less downside risk, with a higher minimum return. The larger variability in the managed system is partly due to the flexible number of animals purchased and sold in each year, which in turn leads to greater gross margin variability between years. This is a limitation of annual analysis methods compared to multi-year methods where the long-term benefits of systems that reduce downside risk and variability are better accounted for.



4.3.4.2.1: Box and whisker plots indicating the mean standard deviation (circle), median (vertical line within box), maximum and minimum GM/ha return for the Glen Innes Cattle Baseline (BL) and Managed (MG) scenarios.

4.4 Lookup Table

4.4.1 Development and testing of the lookup tables

The lookup tables have been developed as the method for delivering the web-based interactive learning tool to objectively assess the type and timing of tactical decisions for use by producers and extension professionals. The lookup tables are currently Excel® based but will be developed in a web format with the redevelopment of other DPI drought management tools. This will ensure an integrated approach that allows the assessment of risks of different management options using the tool developed in this project and individualised approaches to costing decisions with tools like Stockplan.

The design of the tool was planned through a consultation process with two stages. The first stage involved presenting a draft structure to three advisory staff experienced in the development and use of drought management tools. This consultation was first held with external industry expert and after revisions a further consultation was held with two NSW DPI stuff with in-depth understanding of the livestock grazing system. The format for the tool was then tested with two producers from the Monaro region before the format was finalised.

Some of the key refinements and comments are listed below.

Advisor comments

- Compare how decisions perform under different seasonal conditions.
- Link to Impact software in Stockplan for producers to make their own decision.
- The tool includes seasonal risk, which is not included in other tools.
- Small glitches in software can turn users off very quickly, get it right before it is released.
- Minimum 5-year cashflow to account for flock dynamics.
- Link between decisions going into drought and those coming out need to be clear.
- Include feed on offer and ground cover if possible.
- Supply enough background information so that producers are able to clearly understand the system and decisions.
- Have an easy way of clicking back from a decision to change an option
- Make sure the information is based on whole farm cashflow.

Producer comments

- The rainfall needs to be labelled in a user-friendly way (e.g. above average, below average) and possibly with mm of rainfall for the location.
- Don't use feed-on-offer levels as harder to interpret.
- Need somewhere to drill down into the details of the farming system.
- Have a simplified version of the enterprise (one year) and have the decisions as a popup box when you float over the time of year.
- Which decision do I make – Make this check boxes. Have a back button to change scenario (from the output table) so that options can be changed relatively easily.
- The month of year a better descriptor than stage of production cycle, but the user will need to understand both.
- Financial outputs look good, but comments on pros and cons could be provided.

- We need to have a clear description of what is included in the tactical modelling e.g. extra animals retained in restocking periods, whole-farm cash flow.

4.4.2 Lookup tool operation

The lookup table is designed to be simple user-friendly tool. Users can make informed feeding and selling decisions using dropdown menu.

- Selected the required region (seven regions)
- Select the type of enterprise (sheep/cattle)
- Select the expected rainfall decile
- Select the input cost (low, medium or high)
- Select the current product price (low, medium or high)
- Select the management system (Baseline (default) system or Flexible (tactical) system)
- Compare the profit or loss of the two management systems to make decision.

4.5 Rangeland modelling and analysis

The main trigger point identified through consultation with producers was adjusting ewe numbers in August based on available feed. Box 4.5.1 shows selected producer comments that support the timing and level of reduction in ewe numbers to be investigated. The model validation also supported the timing of the peak available feed is in August (Figure 4.5.1).

Box 4.5.1: Selected producer comments on August as a Trigger Point.

Producer 1*: "End of August is the best time to assess the season – most of good tucker grown in winter and so know by then how many you can run over the summer. Even if [we] get 2 inches over summer, it helps the bush but doesn't really change your game plan".*

Producer 2*: "Last year gone through winter without any rain and came to August when a long way to winter again, so made the decision to get rid of everything >3yrs".*

Producer 3: *"Rainfall at the end of the winter growth period is the trigger point. Last winter went from 3000 to 1500 ewes because of the rainfall deficit".*

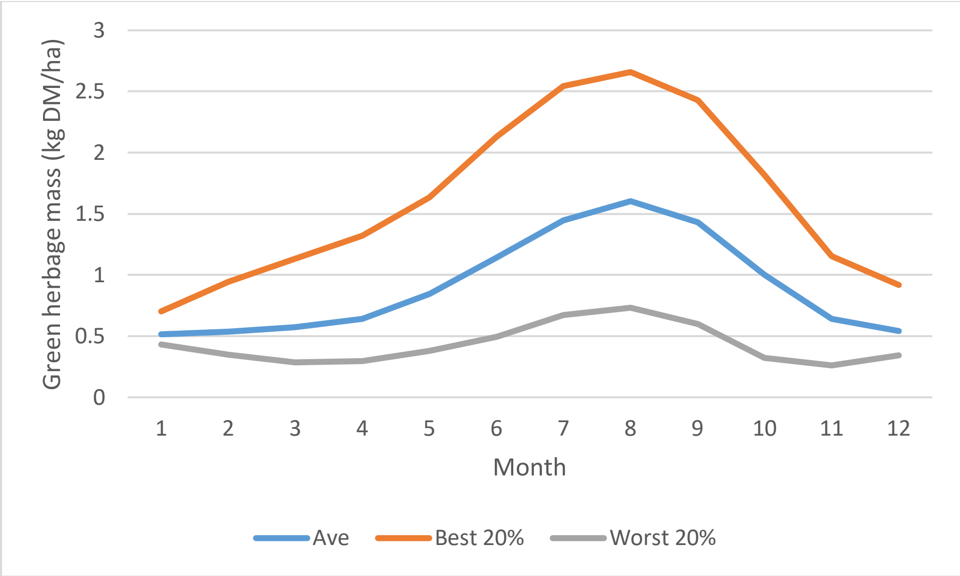


Figure 4.5.1. The green herbage mass for the average, Best 20% and worst 20% of years for a grazing system stocked at Balranald predicted using the SGS pasture model. The green herbage mass peaks in August and is generally lowest from January to May.

The system investigated in the analysis was Merino ewe (60 kg reference weight) joined to a terminal sire with lambing on the 1 June and lambs sold on the 1 November or at 50 kg and run at stocking rate of 0.1 ewes/ha (Figure 4.5.2).

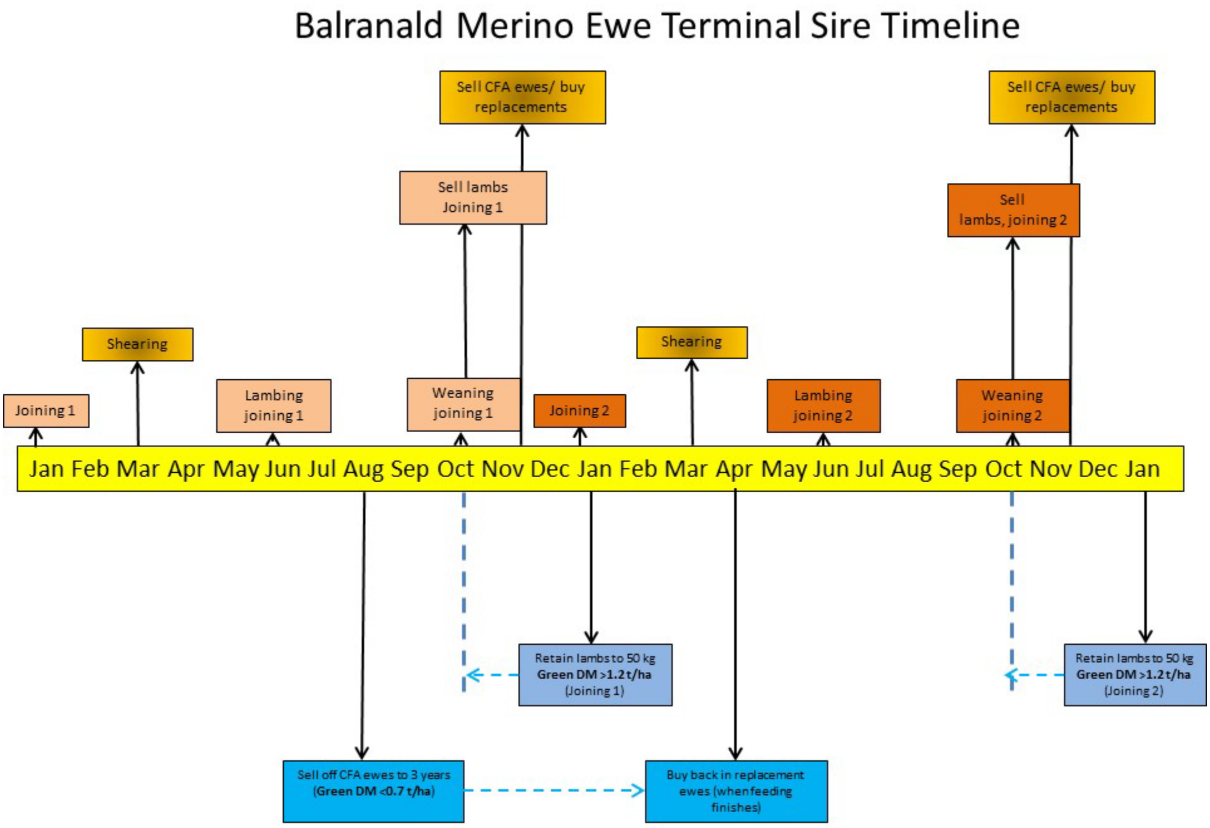


Figure 4.5.2. Timeline for the management of merino ewes joined to a terminal sire at Balranald

4.5.1 Management Decisions

There are two flexible decision comparisons

1. Adjusting ewe numbers:
   a. *Base system,* June lambing, lambs sold on 1 Nov with ewes retained and supplementary fed in a drought lot; compared to
   b. *Flexible ewes sale,* June lambing, lambs sold on 1 Nov with half ewes sold when green herbage mass in August is <0.7 t DM/ha.
2. Adjusting sale time of lambs:
   a. *Base system*;
   b. *Flexible lamb sale - 1.2,* June lambing, lambs sold on 1 Nov or lambs sold at 50 kg when green herbage mass in October is >1.2 t DM/ha, and ewes are retained and supplementary fed in a drought lot;
   c. *Flexible lamb sale – 0.5,* June lambing, lambs sold on 1 Nov or lambs sold at 50 kg when green herbage mass in October is >0.5 t DM/ha, and ewes are retained and supplementary fed in a drought lot; and
   d. *50 kg lambs*, June lambing, lambs sold at 50 kg and ewes are retained and supplementary fed in a drought lot.

There were two types of management decisions that were evaluated to adjust to variations in feed availability between season. The first was to reduce ewe numbers by half when green herbage mass was <0.7 t DM/ha in August. The second was to retain lambs to 50 kg if green herbage mass in October was either > 1.2 t DM/ha or >0.5 t DM/ha. Post processing was used to adjust supplementary feed in the base system to simulate the sale of livestock based on the number of days the animals were confinement fed in the model (paddock 1 or 1 ha feedlot) for the Flex ewe system. For the two flexible lamb sale scenarios, years where the trigger point were met the 50kg data was used and the base system data was used where they were not (see Appendix 8.2 for details of how green herbage mass was comparable between scenarios and all operation were confined within the calendar year so year could be interchangeable).

4.5.2 Rangeland results

Flexible ewe numbers did not make a great deal of difference in profitability compared to the base system, and on average the base system was $2.49/DSE more profitable ($P < 0.001$; Table 4.5.1). This does not match the expected advantage identified by producers of selling off ewes in poor seasons. There was an interaction between sheep price and the difference in the flex sale of ewes and the base system ($P < 0.001$). At a moderate sheep price there was no difference between selling or retaining ewes, while there were benefits to the base system at the high and low sheep price.

To look at these decisions in more detail, first the analysis was restricted to years where green herbage mass in August was <0.7 t DM/ha as this is when the decision was made. We examined one or two years following the trigger point for the decision, to get a better understanding of the impact of the decision on the income in the year of the decision and in the following recovery year (there were only two years where the benchmark occurred back-to-back). The results showed across all price scenarios (there was no significant interaction between treatment and sheep or grain price), there was not a difference in gross margin in the year the decision was made, but in the following year there was higher a $5.35 higher gross margin with the base system than the flex ewe sale

(P<0.001; Figure 4.5.3). The additional livestock income from the sale of livestock as well as reduced feeding costs helped the flex ewe sale in the first year, but in some years the ewes were bought back in within a month and this impacted on profitability. Even if these instances where ewes are bought back in within a month are excluded from the analysis then profitability was still not improved significantly (data not presented). In the second year following the decision the Flex ewe sale had increased cost of buying ewes back in and in some instances lower lambing rates where ewes were not bought in time for joining that contributed to the lower profitability compared to the base system. Unfortunately, the approached used limited a staged approach of selling down ewes gradually rather than in one large hit.

For producers who do not have much experience with feeding ewes or do not have the labour and infrastructure in place then they are likely to judge selling as a safer option, even though returns are slightly lower at high or low prices and are more variable (Figure 4.5.3). Also, while the modelling more clearly quantifies the risks of selling livestock, it also assumes ideal management of livestock and the risk around protracted feeding and animal health issues is probably not fully accounted for in this analysis.

Table 4.5.1. Average gross margin per DSE (Long-term average) for different management treatments, sheep prices and grain prices. The management treatments included: 1) Base system - all ewes retained, lambs sold 1 November; 2) Flex ewe – ewes reduced when August green DM <0.7 t DM/ha, lambs sold on 1 November; 3) Flex lamb - 1.2 - all ewes retained, Lambs retained to 50 kg when October green DM >1.2 t/ha; 4) Flex lamb – 0.5 - all ewes retained, lambs retained to 50 kg when October green DM >0.5 t/ha; and 5) 50 kg lamb: all ewes retained and lambs retained to 50 kg. High (0.9 decile; or based on 2020), Medium (average) and Low (0.1 decile) sheep prices CPI adjusted over 20 years. High (0.9 decile; or based on 2020), Medium (average) and Low (0.1 decile) feed grain prices CPI adjusted over 20 years. P values and least significant difference (P<0.05) are presented.

System		Treatments					lsd	P-value
		Base	*Flex ewe*	*Flex lamb - 1.2*	*Flex lamb - 0.5*	*50kg lamb*		
Management		$23.04	$20.55	$26.76	$33.30	$35.84	$0.51	P<0.001
		High		*Medium*		*Low*		
	Sheep price	$48.82		$26.63		$8.24	$0.40	P<0.001
		High		*Medium*		*Low*		
	Feed grain	$21.34		$28.29		$30.36	$0.40	P<0.001
Management	**Sheep price**	*Base*	*Flex ewe*	*Flex lamb - 1.2*	*Flex lamb - 0.5*	*50kg lamb*	$0.89	P<0.001
	High	$41.34	$40.00	$46.64	$56.09	$60.02		
	Medium	$21.52	$21.05	$25.13	$31.50	$33.95		
	Low	$6.27	$0.61	$8.49	$12.31	$13.54		

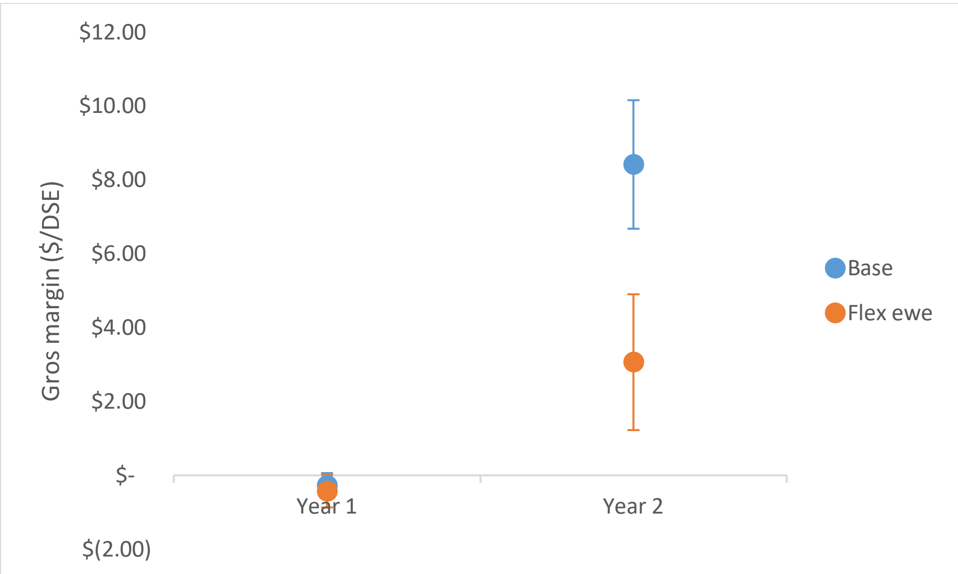


Figure 4.5.3. Difference in gross margin per DSE (long-term average) for the base system and Flex ewe sale in the year the trigger point decision is made (Year 1) and the average of two years (Year 2). The data presented is the average of all nine sheep price and feed grain combinations. Standard error bars presented.

It can be assumed even at very high supplementary feeding costs that the depressed income in the years following the drought can often override any short-term benefit from selling ewes to avoid feeding. In this analysis the different sheep sale scenarios assumed that the CFA sale price was approximately 30% lower, but varied depending on sale weights and specific price scenarios of the cost to buy stock back in. While in practice the sale of stock may target lower productivity stock, in this analysis there is no assumption about any difference in stock genetics between those sold during a drought and those bought back in after a drought. A sensitivity analysis was used to assess to impact on profitability between the flex ewe and the base systems in all years and the years when flexible decisions were made of replacement ewe prices that were 0, 30, 60 and 90% higher than the CFA sale price under the current high price scenario (Table 4.5.2). On average over all years there was little difference between systems, when focused on the years when flexible decisions were made the gross margin went from a $11/DSE benefit to the Flex system when sale and purchase prices were comparable to a $12/DSE benefit to the base system when replacement price was 90% higher than the sale price.

Table 4.5.2. Difference in gross margin per DSE (long-term average) for the base system and Flex ewe sale when replacement ewe prices were approximately 0, 30, 60 and 90% higher than the sale price at the Flexible decision. Data is presented for the all years and the years when decisions were made.

		All years		Flexible years	
Replacement ewe price	**Increase on sale price**	**Base**	**Flex ewe**	**Base**	**Flex ewe**
$170	0%	$40.87	$41.08	$9.29	$20.29
$220	30%	$34.97	$34.14	$3.39	$6.72
$270	60%	$29.07	$27.19	-$2.51	-$6.85
$320	90%	$23.17	$20.24	-$8.41	-$20.41

The second way to adapt to seasonal conditions was to grow lambs to a heavier weight if there was adequate feed. The analysis showed that under all price and feed scenarios, the more often animals could be retained to 50 kg, the greater the average profitability (Table 1). Even with significantly increased supplementary feeding below 0.5 t DM/ha of green herbage mass (Appendix 8.2), there was still an advantage as this occurred for a relatively short period of time (2 months) to increase the value of lambs. This indicates that increasing returns from lambs through feeding to a higher weight is a mechanism for overcoming increased expenses in droughts due to feeding or differential in price with the sale of ewes and, provided feeding is possible, lambs should not be sold earlier even in poor seasons.

It is important to note that the analyses that have been done assumes that there is infrastructure, equipment and labour available for confinement feeding rather than feeding in paddocks where significant damage to vegetation can occur. If significant investment is to be made into infrastructure and equipment, then a return on investment to the business would need to be assessed against the benefits to the business. The analysis showed there were also points when feeding occurred in autumn and continued though, so in practice producers would likely have commenced feeding earlier and the sale of ewes might also have been earlier. Finally, it is important to note that the model is a tool to demonstrate the outcome of different approaches to managing drought and the exact green herbage mass thresholds found will likely vary on individual farms with different vegetation structure and condition.

5 Conclusion

This project used consultation with producer groups to develop an enhanced understanding of the decision-making process they use when adapting to seasonal variability and drought. This process highlighted the characteristics of how good decisions are made and the trigger points for their implementation. As decisions are largely subjective, there are perceptions, skills and motivations that need to be understood, before these decisions can be modelled to compare them financially over a range of years. The decisions were able to be modelled in the appropriate complexity in the AusFarm model for production systems in the High Rainfall and Mixed farming zones of south eastern Australia. While in the rangelands the SGS model was used, which had not previously been used in the southern rangelands. It was able to successfully replicate expected livestock production, although the decisions had to be simplified for this modelling platform.

The results of the modelling and economic analysis across all sites show that managed systems with incremental adjustments to stock numbers compared to the baseline systems which did not adapt livestock numbers, generally decreased the risk to producers, but in many situations also lowered profitability. The findings were compiled into a decision support tool that can be used with producers to assess the risk of different decision-making processes. The project has the potential to increase the profitability of the red meat industry in southern Australia with a further adoption phase to engage with producers.

6 Key findings

- Producer consultation found that producers largely use value-based judgements for decisions and recognised the importance of the process and critical dates in decisions.
- Key themes from the consultation include:
    - *strategic preparation in good years* by developing containment feeding lots, developing grain storage or investing in FMD's; and
    - *tactical response to year-to-year variability* by clearly understanding available feed compared to livestock demands, incremental adjustments to stocking rates with sale of the appropriate class of livestock in the production cycle, calculating immediate and future impact of decisions, looking for opportunity to grow extra feed when moisture is available and understand agistment options.
- Due to the relatively low frequency of intense feed deficits that require destocking there is often little impact on average profitability when comparing flexible selling to feeding decisions. However, in the years they are made they can reduce deficits, but this comes at the expense of lower income in recovery years.
- In rangelands, maintaining lambs to a higher sale weight during feed deficits with feeding improved profitability and offset the cost of feeding or replacement cost of ewes if selling.
- The SGS pasture model can successfully be used in the southern rangelands to model tactical decisions.

7 Benefits to industry

Currently there is software processes for budgeting decisions in drought (e.g. NSW DPI Stockplan and Impact); but this software does not consider the seasonal risks, particularly in the years following a drought for different decision options. The tool will help to address this gap and while not an individual budgeting tool, it can be used in combination with a budgeting processes.

The project will increase the profitability of the red meat industry in southern Australia by increasing certainty of feed supply, better predicting the need for drought feeding at the same time avoiding possible overgrazing and land degradation through an appropriate adoption phase.

The project outcomes with ongoing influence through an adoption phase will lead to:

- Confident producers that are able to make better tactical management decisions to adapt to seasonal conditions and improve whole-farm profit and reduce degradation
- Improved modelling capacity and ability to assess tactical management decisions in a range of farming systems.
- Producers that are able to predict pasture growth and animal production in the medium term
- Reduced risk of land degradation and financial loss for producers

There is a clear need for an adoption phase to ensure the projected impact of this project is possible. This will first require a wider validation of the tool with producers, as validation with the completed tool has not been possible. This may require some adjusting of the tool and output to better meet their needs.

8 Future research and recommendations

There is a clear need for an adoption phase to ensure the estimated impact of this project is possible. This will first require a wider validation of the tool with producers, as validation with the completed tool has not been possible in the project. This may require some adjusting of the tool and output to better meet their needs. This validation will involve evaluating the tool with individual producers from each of the groups that were part of project, plus additional producers who were not part of the current phase of the project. This will also involve the competition of the approach used with the SGS model for the rangelands to be completed at Broken Hill.

The tool has been developed in an Excel® format, which can be hosted on websites in it's current form, but there is also an opportunity to develop it into a web front end with existing or new software (e.g. stockplan) for producer to calculate the impact of their own drought scenarios. Having these two components was identified by advisors as being important for the impact of the tool.

The current research could be further developed to increase the impact to industry in a number of ways. This includes:

- Increasing the number of sites and farming systems in the tool to broaden it's relevance.
- Examine the impact of future climate scenarios, to determine whether the recommendation based on historic conditions is relevant under projected future climates, particularly where the intensity and length of extremes will likely increase.
- The role of new farming systems (e.g. with a new feedbase or livestock genetics or production system) can also be examined to determine whether they enhance the tactical management options available to producers or alter the timing of when key decisions are made in the farming system.

Ultimately this tool will help producers identify key decision time points and let them assess different tactical management options that are available to them.

There were some key learnings about the use of models used to model the livestock production systems. We chose the AusFarm to model systems in this project because it gave flexibility in the manager script to better represent the decision-making process producers use. However, with this type of modelling script comes a high investment in time to ensure the complexity of the model represents the decision making as planned and that there are no errors in the modelling output. A simpler approach was used in the rangelands with the SGS model, after the ambitious plans to use AusFarm in the rangelands was not able to be completed in this project. The SGS model had not previously been used in the southern rangelands and it is relatively quick to validate and develop a system for analysis. However, there were some real challenges representing the flock dynamics of a self-replacing sheep system and the tactical decisions as they are implemented on-farm. Hence the analysis using this model was more simplistic, but it was much easier to examine more of the 'what-if' scenarios. There is a real need for a simpler front-end for implementing management of complex stocking decisions, but in a model that is complex enough to supply robust data in a range of environments (e.g. Grazplan or SGS).

Acknowledgement

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Appendix 1. Summaries of producer's workshops

Bookham, NSW

Context

Using a facilitated interactive process, 8 producers from the Bookham Ag Bureau met at Bookham Hall on the 23 August 2018 to provide their experience in managing feed variability, particularly relating to the drought experienced over the first 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the Southern Tablelands region using whole-farm modelling.

Key points

Representative farm system

- Representative farm system: Self-replacing, medium wool, Merino ewe enterprise with 20-30% wethers component. Cropping is mainly to support livestock.
- Average farm area is 500 ha (10 paddocks of 50 ha each) allowing for the splitting of mobs. Pasture species include: annual ryegrass, subclover and microlaena.
- Key dates are: April joining, September lambing, November weaning (shearing of weaners) and December shearing of main flock.

Strategy for managing livestock in 2018

- Critical decision point: before winter and in mid spring.
- Basis for decision included: 12 month rolling rainfall, DSE/100mm of rainfall and grazing charts, seasonal updates on feed availability projections, experience and value based judgements.
- The core strategy was to maintain numbers. Some sold early, but feeding has been the main strategy to maintain genetics.
- The decision to feed was based on high wool prices, relatively benign weather forecast, and scanning results.
- Approaches included: Farm Management Deposits (FMDs) used as a reserve to buy grain; buying grain and quality hay early; harvesting and storing grain; supplementation within paddocks; fully feeding in a feedlot or sacrifice paddock; reducing numbers through a progressive hierarchy of selling (wethers are a release valve; trade stock first); reducing sale weight targets to lighter lamb markets; using larger areas of gibberellic acid to increase winter feed; and using grazing crops earlier than normal.

Tactical decision-making: how when and why

'The time of the production cycle determines the action you take and the animals that can be sold'

- Process: subjectively assess pasture for quantity and quality, some use objective assessment when approaching the limit of feed availability; feed when "Getting tight"- not reaching target growth rates and condition score; assess requirement (weaners, single and twin bearing ewes); valuing genetics so less likely to sell; market information (prices and trends); fodder stored (silage and hay).
- Where: If rains bring animals into a feedlot or sacrifice paddock to allow country to get away.
- Feed source: preferably feeding barley to sheep and hay to cattle.

- Selling surplus stock: early sale of older stock then dry ewes; wethers in preference to ewes; cattle traded in better years to reduce disease risk; shear sale animals early – staple length >65mm.

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- How do different strategies for maintaining wethers, retaining for 4 months, 15-18 months or 4 years; help to adapt to seasonal conditions? Wethers will be incrementally sold down, with strategies like early shearing, to adapt to seasonal conditions.
- Is it better to prepare for drought by storing money in FMDs or investing in grain storage infrastructure? Also test the effectiveness of different grain buying strategies.

Broken Hill, NSW

Context

Using facilitated interactive process, seven producers from the far North West region met at Broken Hill to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Self-replacing Merino or Dorper (with 3 joinings in two years) sheep with trading cattle and a rangeland goat component (harvested and not managed), 60/20/20 (sheep, cattle, goats). About 20% of land left for goats
- Open mulga/annual grass, and downs country with bluebush country. Bluebush country has the bush as a backup feed reserve as it dries out. Average farm area is 40,000 to 80,000 ha and at least one watering point per paddock.

Strategy for managing livestock in 2018

- Core strategy: progressive feeding and reduction of numbers, agistment, conservative stocking, feed lotting ewes or lambs, sell all stock and work off-farm until condition improve, shear early and sell, running ewes dry to reduce feeding costs, and licks in bluebush country. Stock adjustment times at shearing, crutching and scanning – whenever you have them in the yards.
- Ewes slipped in condition quickly as rain stopped. Decision to feed was based on: wool prices, weather forecast, soil moisture levels and scan results

Tactical decision-making: how when and why

'Normally trade when feed is still growing – if green goes stock goes'

Process: assess pastures for quality and quantity; animal condition score, market information (price and trends); agistment availability; fodder stored (silage and hay). Assess total grazing pressure, including kangaroos. The initial feedbase trigger is decreasing ground cove, neverfail (*Eragrostis setifolia*) and crowsfoot (*Eleusine indica*) are the first to go. Try and get rid of livestock while they are still making a decent return. Make decisions well in advance – try to find somewhere to put them to maintain or improve them in the hope conditions improve, and to conserve country by not overgrazing. Short-term leasing of livestock is a novel approach instead of agistment.

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- Do different stocking rates, and triggers (e.g. ground cover and green biomass, livestock condition) for feed lotting of core breeding stock influence whole farm profit and sustainability?
- How do different triggers (e.g. ground cover, livestock condition) for trading (sell down and buying in) influence whole farm profit and sustainability?
- Assess whether 1) short-term leasing of ewes, 2) agistment, 3) joining as normal or 4) keeping ewes dry is the best strategy to get through dry periods in the rangelands?

Orange, NSW

Context

Using facilitated interactive process, six producers from the Central Tablelands of NSW met at Orange to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

A decision was made to focus on a sheep only and cattle only system, as it was viewed there would be conflict between systems about which decisions would be made. There was also a belief that the dominant enterprise should be the focus in dry time

- Average farm area is 1000 ha 50% Basalt/alluvial, 30% mid slope shale and 20% light gravel. Pasture species include: Oats/ forage cropping; Phalaris (C3 perennial grass), sub clover, Microlaena stipa/danthonia.
- 10 DSE/ha either self-replacing cow/calf herd or Merino ewes with ~25% joined to terminal sires.
- Key dates are:
  - Sheep - April joining, December weaning and May lamb sale time;
  - Cattle – November Joining, weaning March/April, Calves sold March to July, Cows sold March to May.

Strategy for managing livestock in 2018

- Early weaning and lamb sale
- Scanning and selling dry animals,
- Staged destocking based on time of year, market demand/ price (least profitable animals in the long-term go first)
- Feeding out hay made on the property (less people doing this now, questioned whether it was better to sell the hay and feed something else)
- Feed dry cows to sell at larger weights and better condition
- Manage joining to avoid pasture degradation
- Early weaning to reduce demands

Tactical decision-making: how when and why

'Time of year determines the decision'

- Decision could be influenced by emotional connection to livestock including as a result of effort to develop genetics as well as financial needs at the time.
- Assess risks such as the likelihood of rain in different seasons; livestock conditions; financial position; feed base and grazing needs.
- Decision to feed is made after doing the figures; early weaning and early selling in dry years. Maidens and older cows are sold after scanning.
- Feed deficits assessed using rolling rainfall and visual (livestock and pasture) assessment
- Process: assess pastures for quality and quantity; animal condition score, market information (price and trends); agistment availability; fodder stored (silage and hay); input from consultants; discuss with neighbours.
- Make decisions incrementally, often involves several steps as conditions unfold.
- Critical dates: dates we plan to have an action if conditions have not changed. Assessed based on:
  - Financial position, risk
  - People's perception (what you feel), skills (e.g. some people hate full supplementary feeding) and family requirements (e.g. education commitments)
  - Assess pasture supply
  - Assess time of year or production cycle
- Critical date is when confidence in feed being available for the next 3 months diminishes

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- In response to feed deficits how does progressive selling down or buying based on different rules (e.g. a minimum of 1, 2, 3 months feed ahead, methods for assessing this based on visual assessment or projected/actual growth and frequency of decisions) influence feed demand and profitability?
- Can early weaning to reduce demands and adjusting sale of weaners be an effective strategy to adjust to seasonal conditions?

Condobolin, NSW

Context

Using facilitated interactive process, eight producers from the 'Central West Farming Systems' met at Condobolin to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Representative farm system: 40% cropping (including permanent pasture and pasture in rotation), 60% livestock (60% cattle and 40% sheep)
        - Cattle: self-replacing Angus/ Hereford
        - mainly joined October
        - Steers sold at 440 kg and heifers at 210 kg
    - Sheep: self-replacing Merino
        - March joining
        - wethers sold at 12 months
    - Permanent native and naturalised pastures (annual rye grass, clover, button grass), oats and Lucerne are the main sources of feed. Forage crops (sorghum) and grain (wheat and barley) are also in the mix. .
    - Cropping: About 50% of land area is used for cropping. Growing livestock feed is a part of the cropping operation.
    - Stock water is mainly surface water with some underground (bore water) and causes a problem during dry times

Strategy for managing livestock in 2018

- Destocking with older mobs going first.
- Try to keep core breeders to maintain genetics for both sheep and cattle.
- Finish lambs on grain and/or Lucerne and sell early
- Early weaning
- Some saw an opportunity in cheap animals and bought cattle in "chasing quick money"
- Scan (pregnancy testing) and sold dry animals
- Decision to feed was based on wool prices, weather forecast, soil moisture levels, scanning results, and home grown feed resources (stored grain and hay).

Tactical decision-making: how when and why

'High livestock prices make a difference to decision making'

Process: visually assess pastures for quality and quantity; animal condition score, market information (price and trends); agistment availability; fodder stored (silage and hay); discuss with neighbours.

- Grain stored from good years in pits or aboveground storage. Hay/silage also made and stored the same way.
- Most additional grain bought from within the region.
- When better seasons return, will increase cropping area to compensate for lower livestock numbers.

- Condition of stock was a bigger driver of feeding than available pasture.
- Sell animals earlier to realise value before the price slips

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- What is the appropriate amount of grain and hay/silage to store?
- What is the value in managing animals to different condition score before feeding/selling?

Tocal, NSW

Context

Using facilitated interactive process, five producers from the Dugong region met at Tocal to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Representative farm system: Angus-cross cattle for the butcher vealers market.
- Average farm area is 200-250 ha (20 paddocks of 10-12 ha each).
- Soil type is 20% flat (14 paddocks); 50% ridge (4 paddocks); 30% hill (2 paddocks).
- Pasture:
    - flat – kikuyu over sown in winter with annual ryegrass and clover
    - ridge – kikuyu and paspalum, 1 paddock over sown in winter with oats
    - hill – C4 natives
- Key dates are: 2 joinings – October and May,
    - Wean 9 months at 260-300 kg, sold directly at weaning
    - Sale: Cull cows at 10 years.
    - Heifers and steers are fattened and sold to MSA market

Strategy for managing livestock in 2018

- Order of stock for reducing numbers:
    - cull older cows first,
    - pregnancy test and sell drys,
    - sell all heifers
- Often use agistment but non available this year. Dry conditions in the region often out of sync with areas further west.
- Most focused on keeping the production system going with supplementation (grain or hay).
- Spare paddocks set aside to use during feed shortage
- Tactical fertilizer application and strip grazing used
- Irrigation to grow forage or water pasture in regulated rivers is cost effective at $3.00/kg. Water is not available when you need it in unregulated rivers and too expensive.
- More often bought hay rather than growing and conserving forage.

Tactical decision-making: how when and why

'It is not the decision you make but the process you go through'

- Process: Visual assessments of quality and quantity of feed and stock condition.
- Feed cows when they start to drop in condition.
- Previously used cheap grain and large volumes of cottonseed meal
- Usually supplementary feed stock for a maximum of 3 months. Once cows go below 2 score, very hard to get them back; therefore, sell before they get to that.
- Keep replacement heifers rather than older cows – younger cattle are easier to look after.
- Extend number of joinings to offset demands throughout the year, combine mobs to rest pastures.

- Early weaning at 6 months (180-200 kg) to look after cows.

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- Determine the value of silage making, buying hay and grain supplementation; area of fodder conserved and storage capacity of grain/silage on farm profitability?
- Determine the value of different stocking rates and condition score targets for feeding on whole farm profitability and sustainability?

Glen Innes, NSW

Context

Using facilitated interactive process, five producers from the GLENRAC group met at Glen Innes to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Representative farm system: Located at Glen Innes. Two major soil types 'basalt' (100% sown or naturalized) and 'trap' (50% sown, 50% native). The average farm size 600 ha with 40-50 paddocks.
- Two animal production systems:
    - Trading cattle
        - Breed – Angus
        - Buy in weight – 320KG
        - Sell weight 450-480kg
        - Sell time – from November
    - Self-replacing cattle and sheep (50:50).
        - Cattle
            - Breed – Angus
            - Join – October
            - Wean – March/April
            - Sale weaner steers and heifers – 12-18 months
        - Sheep
            - Breed – Merino; Self-replacing medium Merino ewe enterprise (50%)
            - Join – April
            - Wean – January
            - Shearing – July

Strategy for managing livestock in 2018

- For trading enterprises:
    - aggressive decision making;
    - matched stock to fodder – fodder budgeting (March to September);
    - sold the most profitable first;
    - no rain- no buy, put money into FMDs, spring the critical period;
    - started selling when we couldn't see feed 3 months ahead
    - staged buying during spring to match pasture availability

- For self-replacing enterprises (both sheep and cattle):
    - budgeted pasture then planned supplement;
    - bought feed early, went into drought before other areas;
    - fed high value animals (high replacement cost);
    - lower stocking rates, sheep were in better condition so more options

Tactical decision-making: how when and why

'Don't fall in love with your stock'

Process: visually assess pastures for quality and quantity; animal condition score; market information (forward contract options'); agistment availability; fodder stored (silage and hay); water availability; calculate grain and hay on hand based on sheep numbers, use of grazing chart. Critical date for destocking is in March coming into winter. Never buy at weaner sales in autumn – so not to carry unnecessary stock over winter.

What would help?

Better weather (climate) forecast; Pastures from Space type information; up-to-date information on government services e.g. on adapted pasture, reliable market information; exposure to information and experience that helps to make a decision.

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- How do producer goals influence the long-term profitability of a sustainably managed livestock production system? Comparing trading and breeding approaches.
- In response to feed and water deficits, how does progressive selling compared to feeding on profitability and sustainability (in combination with the trading and breeding enterprises assessed above)?

Homebush, NSW

Context

Using facilitated interactive process, six producers from the far Lower Murray Darling region met at Balranald to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Self-replacing Merino (wethers sold <12 months); harvesting goats, opportunistic cattle trade or agistment (small proportion)
- Self-replacing Dorper – controlled joining – 3 in 2 years.
- Saltbush Plains (25%), Bluebush & Belah (65%), Old Man saltbush (10%)
- Stocking rate – 4 ha to the sheep (breeding ewe)
- Key dates are: Regardless of season (store sheep sold in September – always generate good prices)

Strategy for managing livestock in 2018

- Decisions made in August because most growth May to August
- Stocking rate reduced by as much as half, mainly older stock and classed younger sheep
- Young stock sold earlier than normal
- Early shearing before selling
- Rest and recovery time (destock paddocks and reduce numbers)
- Starting to feed early when supplementary feeding in paddocks
- Confining and lot feeding pregnant ewes
- Early weaned lambs into a feedlot (varied from 8-20 kg) in June, usually wean in September
- Condition score ewes off the board in September, started feeding the bottom third that were <2 score to get them up for joining (on feed for 6 weeks until joining)
- Separating twins and singles and fed to requirements
- Delaying joining of younger ewes
- Selling all harvest goats (including underweight- not turning them back out).
- Managing "ferals" – pigs, kangaroos, emus (pigs and emus a particular problem when feeding grain in paddocks).

Tactical decision-making: how when and why

'You can sell down too much when it's dry and you don't have the numbers when it recovers'

Process: assess pastures in August/September to determine how we will get through the summer (quality and quantity); animal condition score, market information (price and trends); agistment availability, use grazing charts and follow closely. Rainfall at the end of winter growth period is a trigger point; planning which stock to be sold well in advance of the decision point and using a staged sell down. When better seasonal conditions return assess buy-in value based on potential income over the first 12 months. Choosing not to increase stocking rate allows country to recover post-drought. Take the pressure of bladder saltbush to allow it to recover.

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- Is it better to a) sell down sheep numbers to available feed; b) only to 50% of breeding flock (e.g. at an August trigger); or c) keep ewes and feed? Staged sell down strategies would be assessed for a and possibly b (e.g. culling unproductive and older animals first).
- What is the value in managing to CS (Condition Score) or lamb production targets compared to keeping ewes alive?
- Recovery tactics following sale (option a above). Is it better to d) breeding as normal; e) keep older ewes plus/minus increased joining frequency; f) use agistment; g) buy in ewes?

Nimmitabel, NSW

Context

Using facilitated interactive process, a group of 12 producers from Monaro Farming System (MSF) met at Nimmitabel to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Bungarby site (basalt), native (50% area) and introduced (50%), Soil type different for each pasture type
- Delegate site (granite), native (50%) and introduced (50%)
- Livestock systems – Most producers have cattle less than 10% of the operation. Trading option for bringing cattle in.
- Sheep enterprise, wethers (~25%), surplus ewes joined to terminals (Surplus fertility?)
- Check for ill thrift (can be adjusted by increasing slope). Sensitivity on native/introduced pastures could be done later.

Strategy for managing livestock in 2018

- Critical decision point: early summer and autumn.
- Basis for decision included 12 month rolling rainfall, DSE/100mm of rainfall and grazing charts, seasonal updates on feed availability projections, experience, and value-based judgements.
- Strategies used included fully fed in a feedlot or sacrifice paddock; supplementation on poa tussock; progressive hierarchy of selling (wethers are a release valve); delayed joining; preferential stocking (i.e. better pasture for lambs and cattle); and locking in grain early.

Tactical decision-making: how when and why

'It is not the decision you make but the process you go through'

Process: assess pastures for quality and quantity (ME, DDM, protein content); animal condition score, market information (price and trends); agistment availability; fodder stored (silage and hay); input from consultants; discuss with other group members and neighbours. Use 12 months rolling rainfall chart. Off-farm income influences decision; Use BOM forecast as a general guide, marginal benefit, but better than nothing, after tax cash position, Seasonal forecast using GrassGro modelling.

What would help?

- Daily updates on feed position, either on a monitoring site (e.g. soil moisture probe) or for individual paddocks/farms.
- Improvements to the drought feed calculator – substitution.
- Extra subdivision or troughs to improve feed utilisation.
- Improved climate forecasting skill

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- How do producer goals influence the long-term profitability of a sustainably managed livestock production system? Producer goals will be assessed by incorporating several variables including risk appetite and likelihood of feeding animals over selling them. Decision making will be assessed on what is most rational (e.g. what is the most profitable on cumulative cash flow) and then compare with limitations in producer perceptions and skills. Sensitivity testing will be undertaken based on making decisions poorly, to assess skill limitations.

- In response to feed deficits how does progressive selling, not joining hoggets and joining all ewes in a Merino enterprise influence feed demand and profitability?
- In order to reduce the time to sale of lambs, how does tactical production feeding, influence feed availability and profitability over a range of seasonal conditions?

Temora, NSW

Context

Using facilitated interactive process, ten producers from the Southwest Slopes region met at Temora to share their experience in managing feed variability, particularly relating to the drought experienced over the last 12 months. This input will be used to assess the profitability and sustainability of different management approaches for the region using whole-farm modelling.

Key points

Representative farm system

- Representative farm system: Self-replacing medium Merino ewe enterprise (50%) and First cross (or merino buy-in replacement ewe (50%). Cropping component could range from 20 to 75% of the property and as much as 25% of the cropping dedicated for grazing. Since risk is greater in cropping, shift towards more livestock systems is possible.
- Pasture species include Lucerne (and hairy panic). Stubble grazing and grain feeding are also part of the mix.
- Key dates are: January to June or July feed deficit period; April lambing to grazing crop for August sales
- With better yards and sheds, sheep enterprise systems are more profitable than cereal grain cropping as the risk is greater in cropping especially if the cropping component is less than 75%.

Strategy for managing livestock in 2018

- In good years, cut a lot more hay and store it. Lambs will be grown to heavier weights and stocking pressure reduced on grazing crops.
- Bailed failed canola crops, mostly fed rather than sold, some bought extra from within the region.
- Prefer to bail failed crops than graze, to maintain some stubble cover.
- Prepare for not so favourable seasons by storing enough grain and hay for set number of sheep; cut numbers to make the feed last longer. Also scan sheep and get rid of dry animals as well as early weaning.
- Bailing some barley and wheat stubbles for mixed rations to complement grain.
- Scanned ewes and sold dry ewes and old twinners
- Sales on Auction plus, bought sales forward
- Kept wethers for wool rather than ewes due to lower requirements grazing on stubble
- Finish sheep in feed lots
- Sow more grazing crops (one crop per mob of sheep)
- If you cut your numbers back in the drought, you prolong the impact of the drought. Generally, little destocking only lambs that are not quite finished or older sheep.

Tactical decision-making: how when and why

'Decisions made 10 years ago to buy machinery to allow for hay making, silos bought to store grain [determine tactical decisions]'

Process: assess pastures and grazing crops and stubble for quality and quantity; animal condition score, market information (forward contract options'); agistment availability; fodder stored (silage and hay) included bailed failed crops and stubbles; water availability; calculate grain and hay on hand based on sheep numbers (Bag of grain per year for every sheep). Mostly fill silos up each year and feed what is needed to stock, sell the excess before the next harvest. If we don't get a decent winter rain and harvest is poor, then this is a warning for the next season. '[Storing grain] is critical – flexibility in sale of grain and storing for livestock production'; 'No storage, no choice'.

What would help?

Better weather (climate) forecast; better handle of actions of minority activists; up-to-date information on government services.

Reliable market information; exchange views with 'likeminded' people.

Proposed modelling questions

Based on the consultation meeting the following questions will be addressed with modelling.

- How do different stocking rates and different proportions of cropping affect profitability?
- Determine if the value of grazing crops and trading to take advantage of better seasons is better than running higher stocking rates?

Appendix 2 Developing trigger points

2.1 Creating trigger point decisions

A combination of monthly total green biomass, mean monthly green biomass, number of grazing days and extractable soil moisture, calculated daily from 1900 to 2019, and their relationship with supplementary feeding were used to develop trigger points.

For the Orange site, for example, monthly total green biomass was compared to mean monthly biomass, and when value is less than 500 000 kg (Average of 500 kg DM/ha), very little improvement occurs over winter (1912, 1919, 1923, 1930, 1944, 1957, 1965, 1981, 1983, 1986, 1991, 2016, and 2018) Figure 5. Total farm green biomass is evaluated on 1 May, and on 31 May. If Total farm green > 500 000 kg, normal sale in November occurs, but if Total farm green < 500 000 kg, excess ewe lambs are sold on 31 May after shearing.

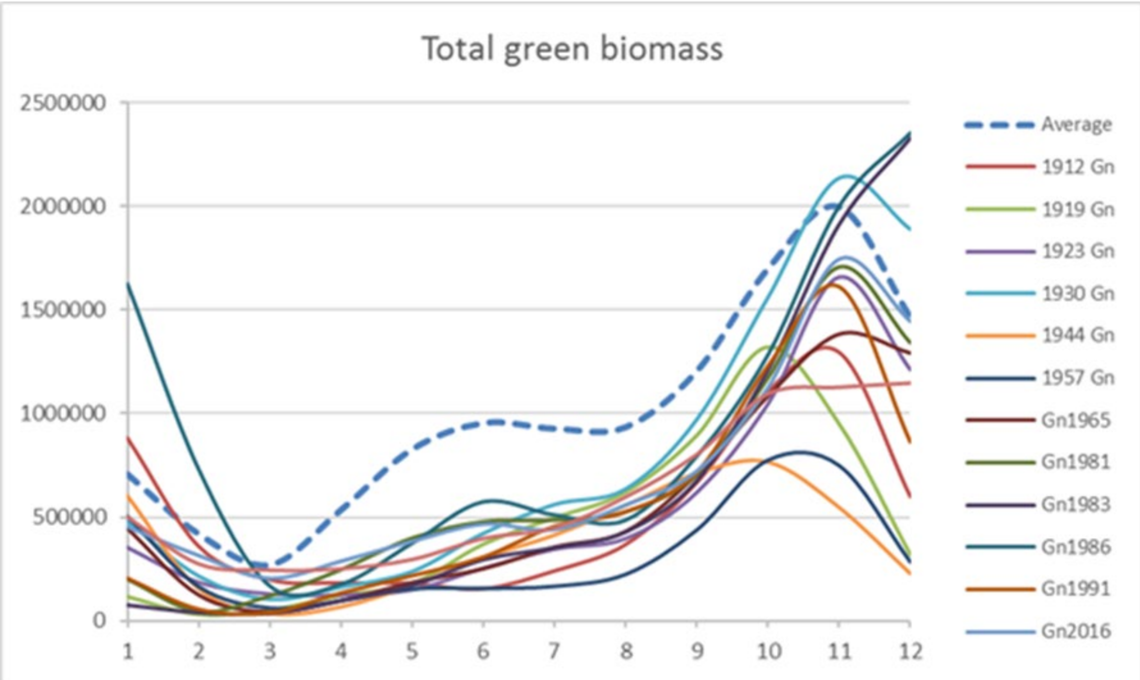

Figure 2.1.1. Monthly total biomass

Moreover, soil moisture in the first 20 weeks of the year greatly influenced green biomass production over winter and early spring. Any increase in soil moisture in late autumn or winter had minimal effect on green biomass production as temperature became the limiting factor to pasture growth (Figure 6). The year 1957 is a good example of this.

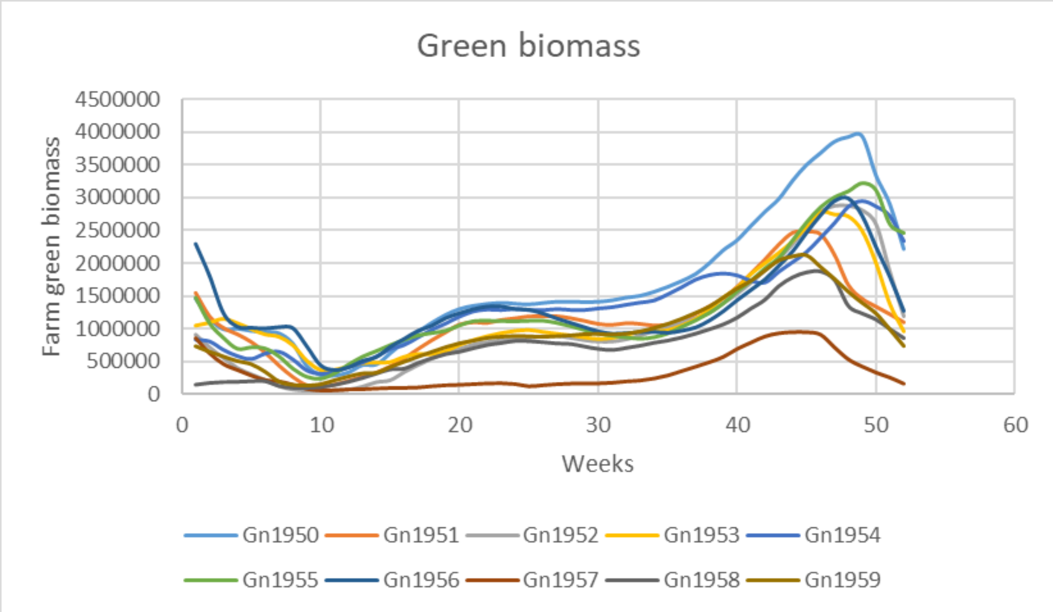

Figure 2.1.2. Weekly farm biomass of certain years.

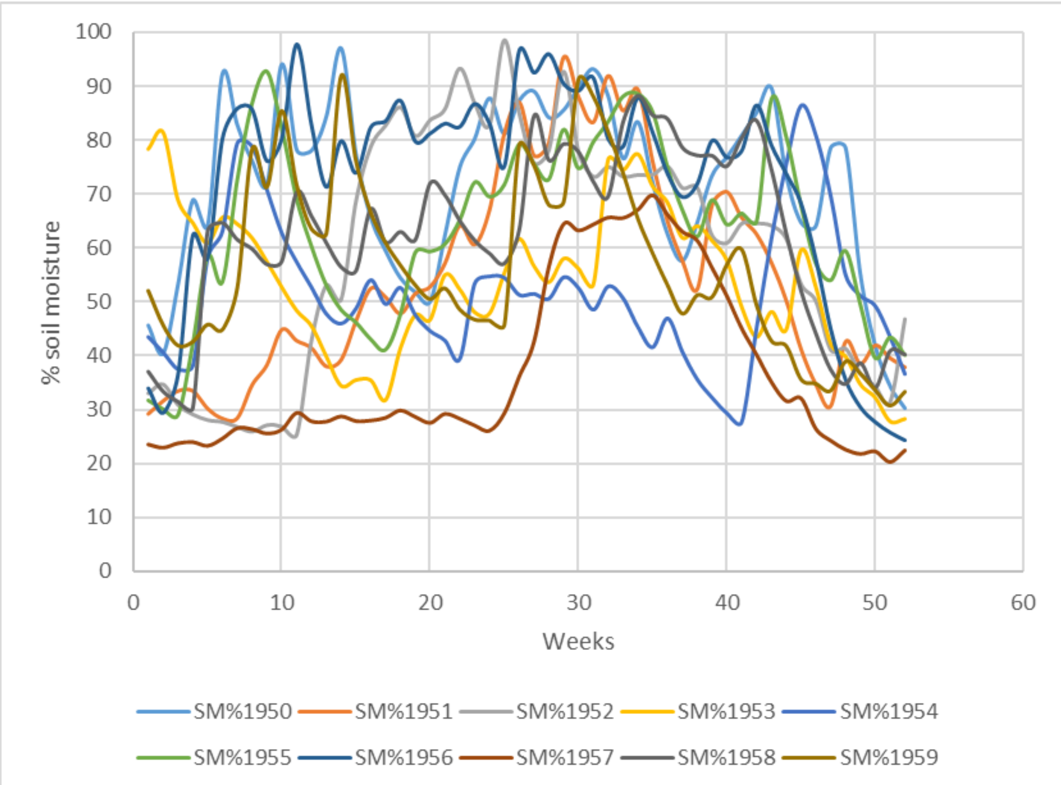

Figure 2.1.3. Weekly soil moisture (%) of certain years

Two factors were selected to determine if the sale of younger cast-for-age (CFA) ewes was to occur – relative soil moisture and supplementary feeding, during the first 3 months of the year prior to joining.

Extractable soil water (esw) for the Rotation paddocks was used.

The maximum esw was determined from long term simulations (208.01 mm), and relative esw (eswREL = esw/208.01*100 %) was calculated at each sample date. The average eswREL for weeks 1 to 6 (esw1_6), weeks 6 to 9 (esw6_9), and weeks 9 to 12 (esw9_12) were calculated. To determine if the soil profile was wetting up or staying at the same level, factors at week 6 (F1), week 9 (F2) and week 12 (F3) were calculated.

At week 6, F1 = eswRELweek 1 + (esw1_6 – eswRELweek1),
at week 9, F2 = eswRELweek6 + (esw6_9 – eswRELweek6),
and at week 12, F3 = eswRELweek9 + (esw9_12 – eswRELweek9)

Total supplementary feed fed to ewes was calculated for the week ending each sample date. If ewes were not fed each week, then sell-off of younger cast for age ewes does not occur. If ewes were fed each week then sell-off of younger cast for age ewes could occur.

Early sell-off of younger cast for age ewes did occur if they were supplementary fed each week, and F1, F2 and F3 < 40%.

Total green biomass

The sheep component of the Glenrac mixed model and the Bookham models looked at total green biomass on the 15th of each month. Critical total green biomass targets were determined at critical times of the livestock systems to determine management decisions.

Grazing days

Total green pasture biomass calculated on the 15th of each month, was divided by the core stock number for each farm multiplied by a factor representing average daily feed requirements for the core stock (eg 20 kg for cow + calf unit, 1 kg for ewe). This was used for Orange cattle, Monaro Farming Systems, Temora, Glenrac cattle (mixed and trading models), Central West Farming Systems, and Tocal.

Monthly grazing days were determined from 1910 to 2019. These were colour coded in Microsoft Excel®, to help visualize low grazing days. Grazing days were grouped in 25 or 50 increments, with the darkest red colour the lowest (0-50 in the Temora model below, 1944 - 1947), with green the highest (200-250 in the Temora model below, 1944-1947). This output was reviewed to identify low grazing day trends within years and align these with activities in the livestock timelines.

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1/01/1944	281	335	285	236	363	334	371	403	492	846	890	333
1/02/1944	148	335	285	236	363	334	371	403	492	846	890	333
1/03/1944	148	85	285	236	363	334	371	403	492	846	890	333
1/04/1944	148	85	78	236	363	334	371	403	492	846	890	333
1/05/1944	148	85	78	111	363	334	371	403	492	846	890	333
1/06/1944	148	85	78	111	246	334	371	403	492	846	890	333
1/07/1944	148	85	78	111	246	112	371	403	492	846	890	333
1/08/1944	148	85	78	111	246	112	180	403	492	846	890	333
1/09/1944	148	85	78	111	246	112	180	270	492	846	890	333
1/10/1944	148	85	78	111	246	112	180	270	372	846	890	333
1/11/1944	148	85	78	111	246	112	180	270	372	250	890	333
1/12/1944	148	85	78	111	246	112	180	270	372	250	150	333
1/01/1945	148	85	78	111	246	112	180	270	372	250	150	71
1/02/1945	32	85	78	111	246	112	180	270	372	250	150	71
1/03/1945	32	22	78	111	246	112	180	270	372	250	150	71
1/04/1945	32	22	19	111	246	112	180	270	372	250	150	71
1/05/1945	32	22	19	10	246	112	180	270	372	250	150	71
1/06/1945	32	22	19	10	11	112	180	270	372	250	150	71
1/07/1945	32	22	19	10	11	21	180	270	372	250	150	71
1/08/1945	32	22	19	10	11	21	64	270	372	250	150	71
1/09/1945	32	22	19	10	11	21	64	115	372	250	150	71
1/10/1945	32	22	19	10	11	21	64	115	334	250	150	71
1/11/1945	32	22	19	10	11	21	64	115	334	580	150	71
1/12/1945	32	22	19	10	11	21	64	115	334	580	700	71
1/01/1946	32	22	19	10	11	21	64	115	334	580	700	188
1/02/1946	90	22	19	10	11	21	64	115	334	580	700	188
1/03/1946	90	148	19	10	11	21	64	115	334	580	700	188
1/04/1946	90	148	252	10	11	21	64	115	334	580	700	188
1/05/1946	90	148	252	451	11	21	64	115	334	580	700	188
1/06/1946	90	148	252	451	401	21	64	115	334	580	700	188
1/07/1946	90	148	252	451	401	124	64	115	334	580	700	188
1/08/1946	90	148	252	451	401	124	117	115	334	580	700	188
1/09/1946	90	148	252	451	401	124	117	155	334	580	700	188
1/10/1946	90	148	252	451	401	124	117	155	190	580	700	188
1/11/1946	90	148	252	451	401	124	117	155	190	137	700	188
1/12/1946	90	148	252	451	401	124	117	155	190	137	89	188
1/01/1947	90	148	252	451	401	124	117	155	190	137	89	101
1/02/1947	141	148	252	451	401	124	117	155	190	137	89	101
1/03/1947	141	144	252	451	401	124	117	155	190	137	89	101
1/04/1947	141	144	109	451	401	124	117	155	190	137	89	101
1/05/1947	141	144	109	140	401	124	117	155	190	137	89	101
1/06/1947	141	144	109	140	243	124	117	155	190	137	89	101
1/07/1947	141	144	109	140	243	195	117	155	190	137	89	101
1/08/1947	141	144	109	140	243	195	228	155	190	137	89	101
1/09/1947	141	144	109	140	243	195	228	252	190	137	89	101
1/10/1947	141	144	109	140	243	195	228	252	357	137	89	101
1/11/1947	141	144	109	140	243	195	228	252	357	723	89	101
1/12/1947	141	144	109	140	243	195	228	252	357	723	973	101

By visualising this data, and lining it up with the livestock timeline, different trigger points could then be determined. For Temora this created:

1. Early sale of excess ewe lambs. Normal sale is November 01, prior to weaning of next cohort of lambs. If April and May trigger <50, sell excess ewe lambs on June 1. (1945 in above example)
2. Sell prime lambs at lower target weight. Normal prime lamb sale target weights are 52 kg for wether lambs and 44 kg for ewe lambs. When January trigger <50, wether prime lambs are sold at 42 kg, and ewe prime lambs are sold at 38 kg. (1945 in above example)
3. Sell younger CFA ewes. If January trigger < 50 and February trigger < 50, younger CFA ewes are sold on February 28. (1945 in above example)

Appendix 3 Rangelands model validation and trigger point development

Introduction

Modelling tactical decisions in rangelands was initially planned to be done with the AusFarm model. However, with the complexities of the model and the limited time in the project to integrate bowse in the diet into the model a separate approach was investigated for assessing trigger points. This involved a process of validating the use of the SGS pasture model for use in the rangeland systems and then investigating trigger points for management decisions. As there was not the same flexibility to implement flexible decisions in the SGS model as is found in AusFarm the investigation of tactical decisions was limited to relatively simple feeding and selling decisions that were relevant to the group from Balranald. The aim of this section of work was to:

1) compare the herbage mass output from the SGS pasture model and the GRASP model (a model validated and commonly used in the rangelands) to determine whether their output is comparable;

2) compare pasture herbage mass and livestock weights to previous data from the saltbush plans at Deniliquin to determine the SGS model accuracy under these conditions;

3) validate pasture growth curves and livestock feeding with producers from the Balranald (Homebush) focus group to ensure the modelled data represented their experience over the last 5 years; and

4) objectively develop trigger points compared to producer experience.

Methods

Comparing models

The SGS pasture model was compared with the GRASP model (a model validated and commonly used in the rangelands) to determine whether their output is comparable and to determine if the SGS pasture model can be used in the rangelands.

The GRASP model is an empirical model which simulates a daily soil–water balance, pasture growth and animal grazing response to climate inputs and land management. The model inputs include daily rainfall, minimum and maximum temperature, evaporation, solar radiation and vapour pressure. GRASP simulates soil water balance, in response to the climate inputs, the processes of runoff, infiltration, soil evaporation and pasture and tree transpiration. The above-ground pasture biomass is modelled as a product of pasture growth, senescence, detachment of standing dry matter, litter decomposition, animal trampling, and consumption. Animal production can be modelled for either sheep or cattle. Forage intake (utilisation) follows feed quality restrictions for the proportion of growth that can be consumed and a limitation for consumption at low pasture biomass levels. The animal liveweight gain is determined as a function of the daily intake, including the duration of grazing.

The SGS pasture model incorporates a physiological model of pasture species herbage growth in response to climatic conditions; the water balance including evapotranspiration, runoff (surface and subsurface), infiltration and drainage; pasture utilisation by grazing animals; a metabolisable energy-based animal growth model; and organic matter and inorganic nutrient dynamics (for nitrogen, phosphorus, potassium and sulfur) including plant uptake, adsorption, leaching, nitrogen fixation by legumes, and atmospheric nitrogen losses. A range of grazing options (set-stocking, rotational grazing and continuous grazing at a variable rate) is available for ewes and lambs, and wethers. Each of the main modules (water, nutrients, pastures and animals) is interconnected. The model is hierarchical in structure and most processes are described in terms of a series of fluxes (or, more specifically, flux densities) that have dimensions of amount per area per time.

In the first step of the study, both models were run using climate data from Cobar. The GRASP model was run from 2000 to 2018 at 15% utilisation (0.25 sheep/ha; mature animals with a 55 kg reference weight), which align with the expected long-term stocking rates of rangeland in good condition in this area. The SGS model was then run for the same period at a similar stocking rate (0.3 DSE/ha or 0.13 ewes per ha) using a pasture consisting of C4 native grasses and subclover (representing native forbs) parameters. The pasture herbage mass was compared for the two models.

Validating the SGS pasture model

One of the main issues with the use of the SGS and other pasture models in the rangelands is that they don't represent the browse component of the vegetation in the animal's diet. The next step was to determine if the SGS model can represent the herbage mass and sheep weight change dynamics measured on saltbush plain rangeland. Data from Wilson *et al.* (1969), investigating Merino sheep grazing a bladder saltbush-cotton-bush community using set stocking at three stocking rates (2.5, 1.2, and 0.6 sheep/hectare) over a 3-year period (August 1964 to May 1967), was compared to the SGS model. The two higher stocking rates of 2.5 and 1.2 sheep/ha dramatically degraded the vegetation with 0% and 2% survival of salt bushes respectively. This degradation could not be simulated by the model, and these higher stocking rates were excluded from the analysis.

The SGS model was established with 0.6 wethers per ha grazing (50 kg reference weight) a C4 native grass and subclover (representing naturalised/native annual grasses and forbs) pasture. The soil used had light hydraulic and low organic matter properties. Weather data was downloaded from long paddock for the coordinates of the study located 50km north of Deniliquin (lat 35.2; long 144.9) with an average annual rainfall of 337 mm. While this area has a low level of trees, the tree level was set at 30% to account for scalding or bare areas where forage is not actively growing. The simulation was run from 1963 to 1970. The modelled herbage mass of the pasture was compared to the measured saltbush and the grass/forb component of the pasture. The modelled and measured sheep weights were also compared.

Testing the model against producer judgement

To develop and test the model for Balranald the SGS model was run. The SGS model was established with 0.25 ewes grazing (60 kg reference weight) a C4 native grass and subclover (representing naturalised/native annual grasses and forbs) pasture. The ewes were joined to a terminal sire with lambing on the 1 June and all lambs sold on the 1 November. The soil used had light hydraulic and low organic matter properties. Weather data was downloaded from long paddock for the Balranald with an average annual rainfall of 317 mm. While this area has a low level of trees, the tree level was set at 30% to account for scalding or bare areas where forage is not actively growing. The simulation was run from 1963 to 2020.

The initial runs had data from 1 January 2016 to 30 June 2020. This covered a high growth wet period in 2016 through to extremely dry years in 2018 and 2019. Output for DM and sheep intake of pasture and supplementary forage were first tested with two advisors working in that area to determine they were within the expected range. After adjustments they were then validated with the producer group used for the consultation in that area and further adjustments were made to the model to better reflect their experience over this period.

Objectively developing trigger points

To develop trigger points for management decisions at Balranald the same SGS model was run as outlined in section 3. The model was used to simulate the levels of green herbage mass and the level of supplementary feeding that occurred in different season. The average green herbage mass was compared to producers comments about destocking decisions and this identified August as a critical time for adjust ewe numbers. The average green herbage mass in this month was then compared to level of supplementary feeding for the following 4 months, to determine the critical tipping points where supplementary dramatically increased. A second point was identified of when lambs could be retained for long in the system. As lambs were typically identified as being sold on 1 November then the October green herbage mass was assessed to determine how this influenced the level of feeding over the following 4 months. The analysis was then used to put together systems and decisions that were assessed in a gross margin analysis (Section 4.5 of the main report).

Results and Discussion

Comparing models

The herbage mass from the two models in compared between 2000 and 2018 for Cobar in Figure 1. Generally, there was good alignment in herbage mass between the two models (R^2 = 0.48), with average herbage mass predicted for the SGS model (957 kg DM/ha) slightly higher than the GRASP model (893 kg DM/ha). The largest difference occurred with the SGS model overestimating production during peak growth periods. While the model growth parameters were clearly different, there were also slight differences in the stocking rate and demands of animals at different times that could have also influenced herbage mass levels.

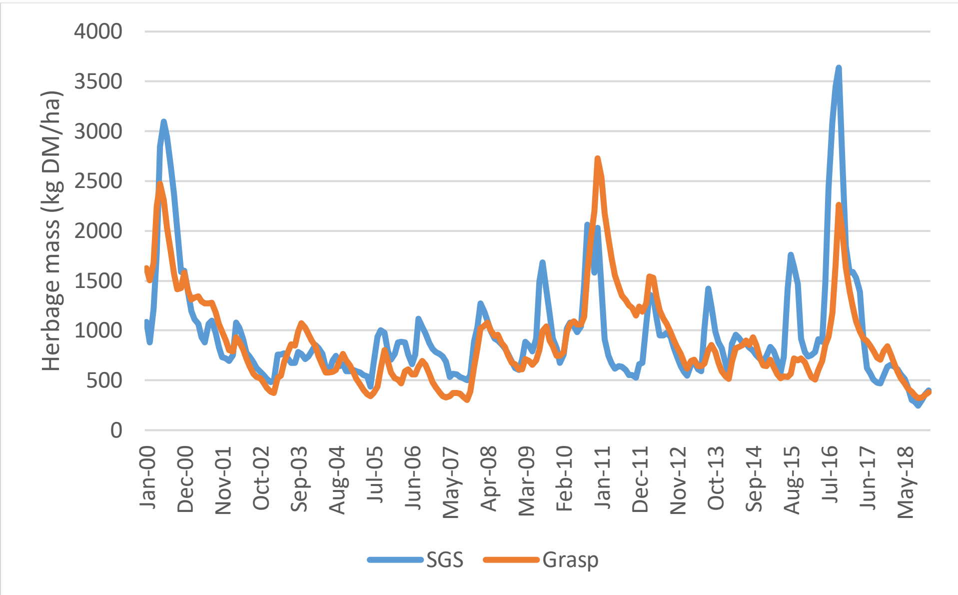

Figure 3.3.1.1. Comparison of herbage mass model output for the Grasp model (run at 15% utilisation or an average of 0.25 sheep per ha) and the SGS pasture (average of 0.3 DSE per ha) at Cobar.

Validating the SGS pasture model

The herbage mass of the grass/forb and saltbush components of the vegetation were compared to the SGS model output (Figure 2). There was good alignment between the pattern of grass/forb herbage mass with modelled herbage mass (R^2 = 0.76; Figure 3), with the measured data being lower than the modelled data. The relationship with the saltbush component of the vegetation was poor (R^2 = 0.11; data not presented). However, a previous study in a similar vegetation has sown that while saltbush is a significant part of the vegetation, it only represents 18% of a sheep's diet (Graetz and Wilson 1980), therefore failure to simulate this component of the vegetation, may not limit the models usefulness in predicting livestock performance. Given that saltbushes are not represented in the parameter set, but they represented ~80% of the vegetation, the under prediction of total herbage mass can be explained (Average modelled DM = 798 kg DM/ha; average measured DM = 1550 kg DM/ha).

Sheep weights were investigated to see whether the weight change inflections that were measured could be reproduced with modelling of sheep weights (Figure 4). The main difference between the measured and modelled weights was the large difference in weights at the start of the period. The modelled weights of sheep were 12.6 kg heavier, possibly due to animals being not fully grown or in poor condition at the start of the grazing experiment. The measured weights had a period of increase up to 55 kg and then levelled off, possibly a month or two earlier then the modelled weight. The earlier weight change in the model would also likely reflect the higher demands of the heavier animal. The measured weights dropped below 50 kg July 1965, but this dip was larger in the model weights. The modelled and measured weights were stable from November 1965 to March 1967, but the measured weights were slightly higher most likely due to animals of a higher reference weight than represented in the model. There was a decrease in modelled weight by May 1967 that was not represented in the measured weight, although occurred earlier in the measured weights at higher stocking rates. Overall, the model did a reasonable job in picking when deficits (decreases in sheep weights) occurred, which is important for flexible decision making.

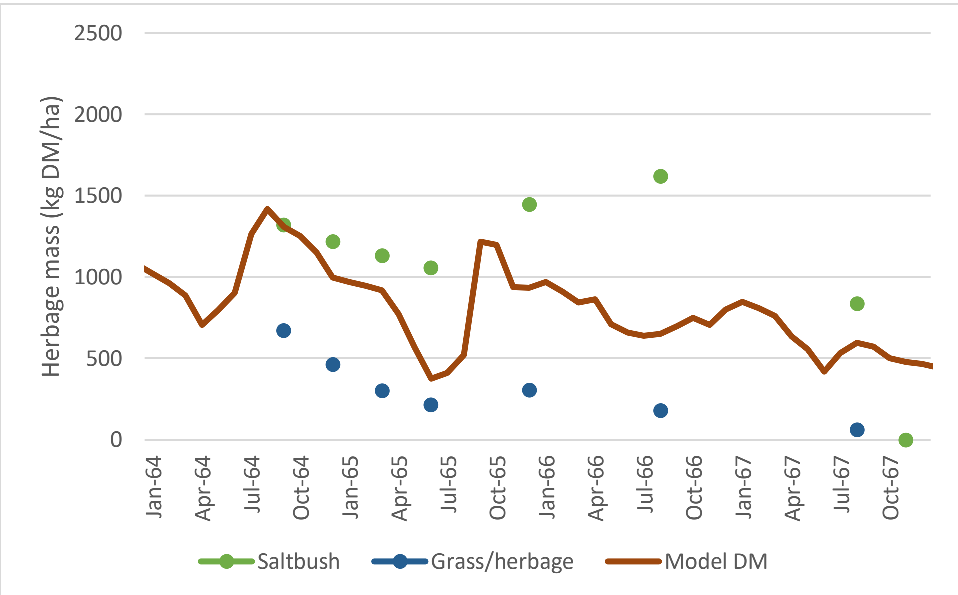

Figure 3.3.2.1. Comparisons of saltbush and grass/herbage mass reported in Wilson *et al.* (1669) with modelled DM from the SGS pasture model using climate data.

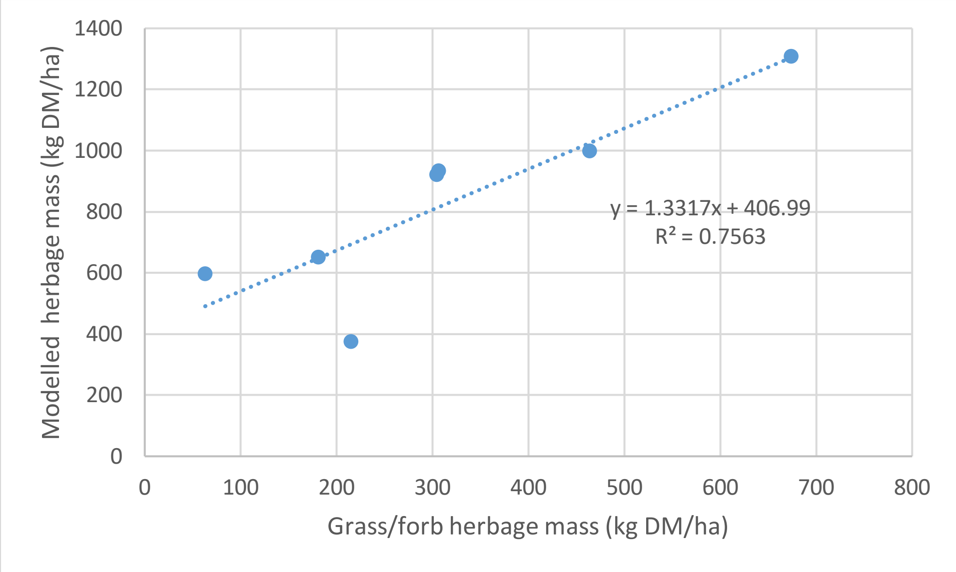

Figure 3.3.2.2. Comparisons of measured grass/forb herbage mass with modelled DM from the SGS pasture model.

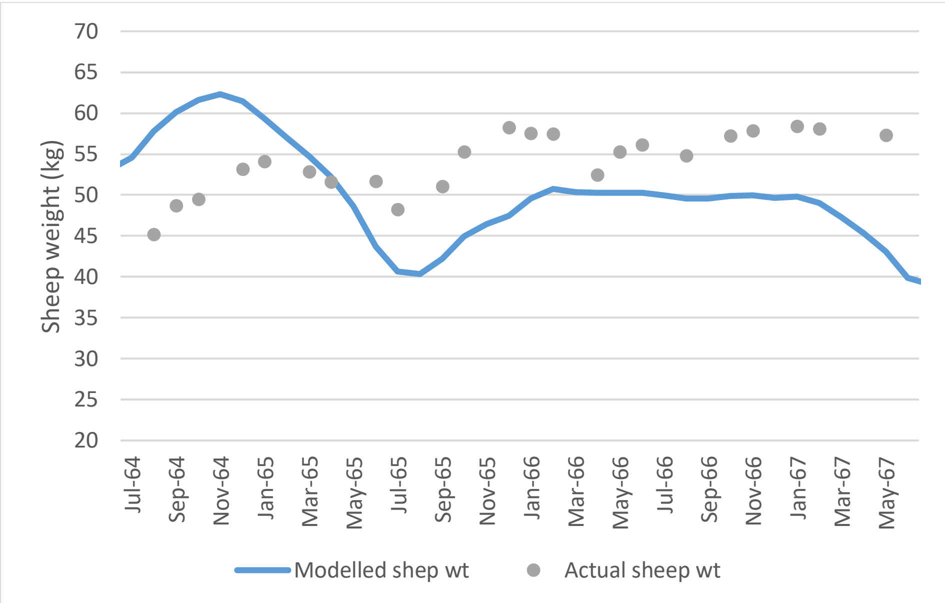

Figure 3.3.2.3. Comparison of measured sheep weights and modelled sheep weights from the grazing experiment

Testing model against producer judgement

The model was run with weather data from Balranald to represent rangeland sheep production systems. The initial runs had data from 1 January 2016 to 30 June 2020. This covered a high growth wet period in 2016 through to extremely dry years in 2018 and 2019. Output for DM and sheep intake were first tested with two advisors working in that area and then checked with the producer group used for the consultation in that area. The primary feedback was the herbage mass looked too high (although browse was not included in the simulation) and that the feeding did not stop through summer 2018/2019. Adjustments were made to the model (Figure 5 and 6) and this was approved by the producer group.

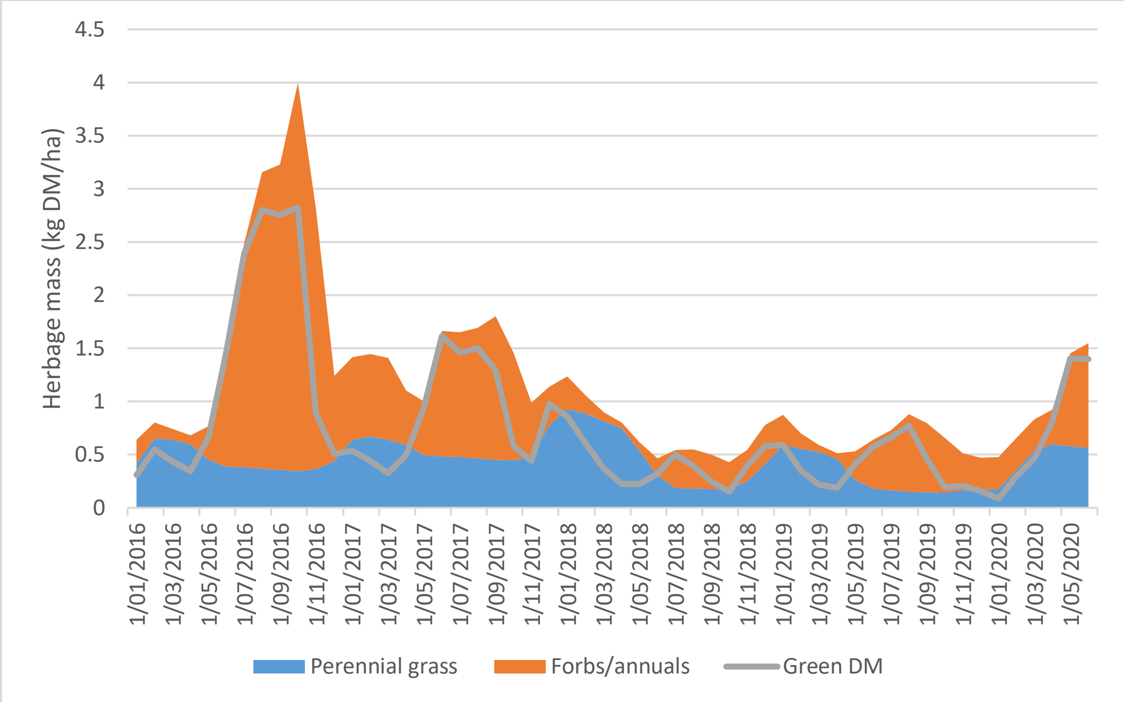

Figure 3.3.4.1. Green herbage mass and composition of perennial grasses and Forbs/annuals modelled for Balranald 1 January 2016 to 30 June 2020 using the SGS pasture model. The output shows the high levels of biomass in the high rainfall year 2016, and through the deficits experienced in 2018 and 2019.

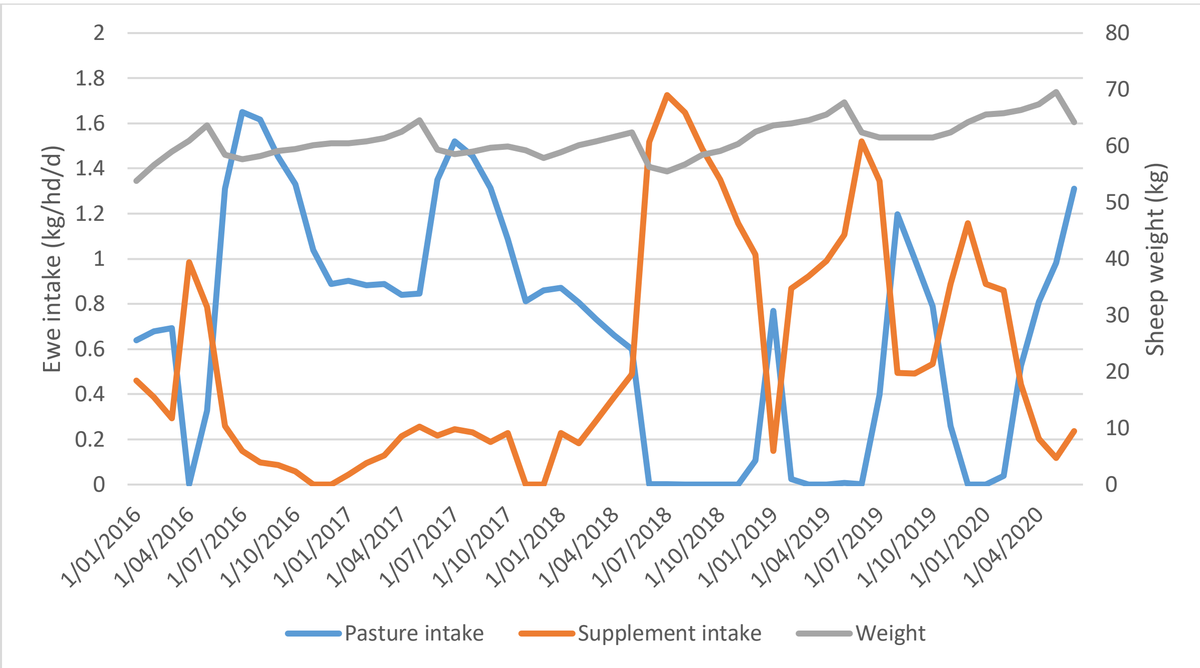

Figure 3.3.4.2. The level of supplementary forage intake for Balranald 1 January 2016 to 30 June 2020 predicted using the SGS pasture model. The output shows the major deficits in 2018 and 2019. Levels of supplement less than approximately 0.2 kg/head/day likely indicate quality deficits that would not see feeding occurring in practice.

Objectively developing trigger points

The producers who took part in the focus group consultation clearly identified that August was a key trigger point for them to make decisions about how to adapt to the coming season. This is highlighted by the three quotes in box 4.5.1. This is further supported by the modelling (Figure 3.3.5.1), which demonstrated that the green herbage mass as a representation of available feed for livestock, peaks in August and then decreases. There is a large variation in the August green herbage mass between years with the average being 1.6 t DM/ha and the highest 20% of years being 2.7 t DM/ha and the lowest being 0.7 t DM/ha.

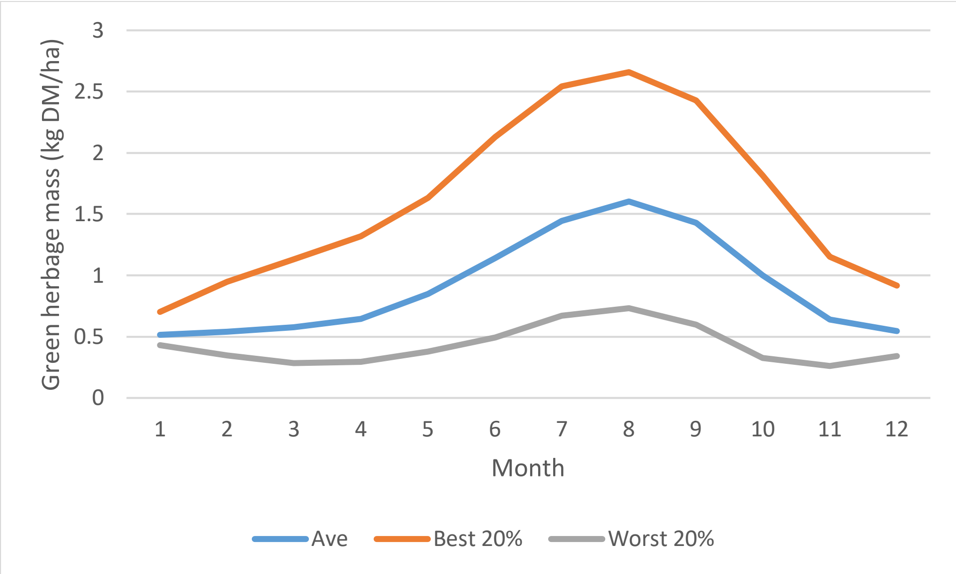

Figure 3.3.5.1. The green herbage mass for the average, Best 20% and worst 20% of years for a grazing system stocked at 0.25 ewes per ha at Balranald predicted using the SGS pasture model. The green herbage mass peaks in August and is generally lowest from January to May.

To examine the August green herbage mass as a trigger point, we determine how much supplementary feeding occurred over the subsequent 4 months (Figure 8). There was a clear change in the level of feeding identified when modelled green herbage mass exceeded green herbage mass levels of 1 t DM/ha. When green herbage mass is <1 t DM/ha the chance of significant feeding (i.e. >0.2 kg/head/day; which would require feeding in practice rather than allowing animals to drop in condition score) is 75%. While if green herbage mass is >1 t DM/ha then the chance of significant feeding was only 5% and the two instances where feeding actually occurred had relatively low levels. Even when the feeding period examined is taken out to the end of March, then the 10% of cases where feeding of >0.5 kg/head/day was required were identified with the green herbage mass trigger of 1 t DM/ha, and this level of feeding occurred 60% of the time with the green herbage mass level of <1 t DM/ha (data not presented). From the calibration data in Figure 2, it is likely the grass/forb herbage mass as a trigger is lower than 1 t DM/ha in practice, but there would also be shrub herbage mass with the green herbage mass available to grazing in excess of 1 t DM/ha.

A second way to define the trigger point was to look at the number of days confinement feeding that occurred from 1 August onwards (i.e. the days from 1 August or when feeding began soon after until sheep exited the feed lot for >30 days). This is an important metric as this strongly influences feeding costs and determines whether selling a proportion of ewes is worthwhile. In the model the sheep cannot return from confinement feeding to graze unless the pasture herbage mass was >0.5 t DM/ha. There were only 5 years (9% of instances) where there was feeding >150 days and this always occurred when green herbage mass was below 0.7 t DM/ha (Figure 9).

A second stocking rate adjustment strategy that assessed was to retain lambs through to a weight of 50 kg when the season allowed. As lambs are normally sold on the 1 November, the October green herbage mass can be used as a trigger point to determine whether there is adequate feed. We compared the October green DM to the amount of feeding that occurred from November to February (Figure 10). There was significant feeding became more frequent when green herbage was <1.2 t DM/ha, with a further upward inflection point in supplementary when green herbage was <0.5 t DM/ha and this these two levels were chosen as points to assess on retaining lambs for longer periods.

While varying stocking rate is one way to adjust to feed deficits. The modelling at such low stocking rates, as is found in the rangelands, does not show large differences even when stocking rate is doubled or halved (data not presented). It is likely that the model does not simulate the degradation that occurs at higher stocking rates. Certainly, this degradation is the form of reduced shrub density was evident in experimental validation presented in section 2. The higher stocking rates were not used in the validation because of this issue.

As there is not an option to adjust stocking rate or lambing and lamb sale strategy between seasons with breeding ewes in the SGS model, we assessed whether this could be done manually. To do this we compared January green DM between 1 November sale and 50 kg sale lambs (which were always turned off before the end of December) and when 50 kg lambs were born in April. The model showed there was virtually no differences in the green DM between times, due to the low stocking rates (Figure 11). Clearly the main driver was seasonal conditions. This enabled output files to spliced together to assess different lamb sale strategies.

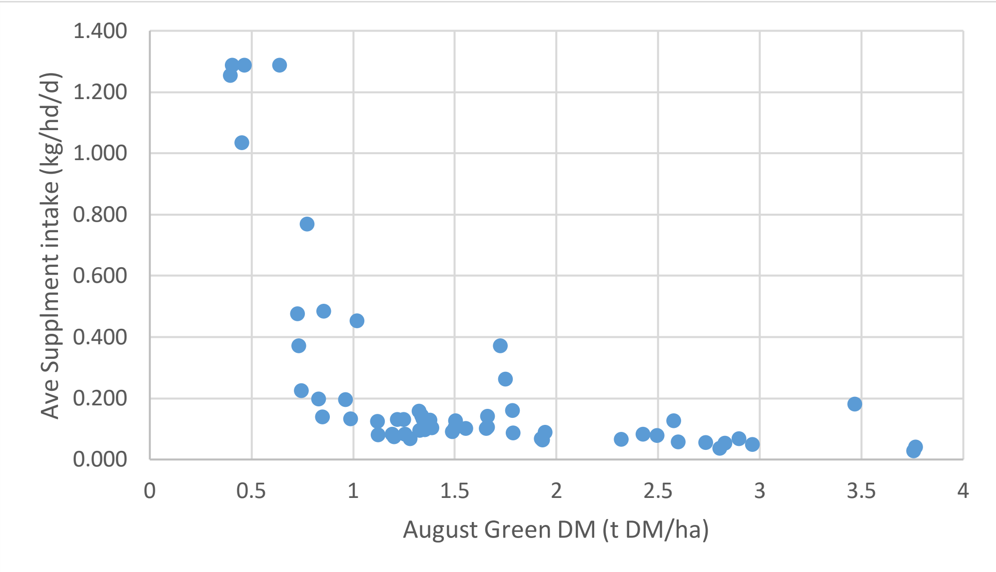

Figure 3.3.5.2. The green herbage mass in August compared to the average intake of supplement (kg per head per day) from September to December for a grazing system stocked at 0.25 ewes per ha at Balranald predicted using the SGS pasture model.

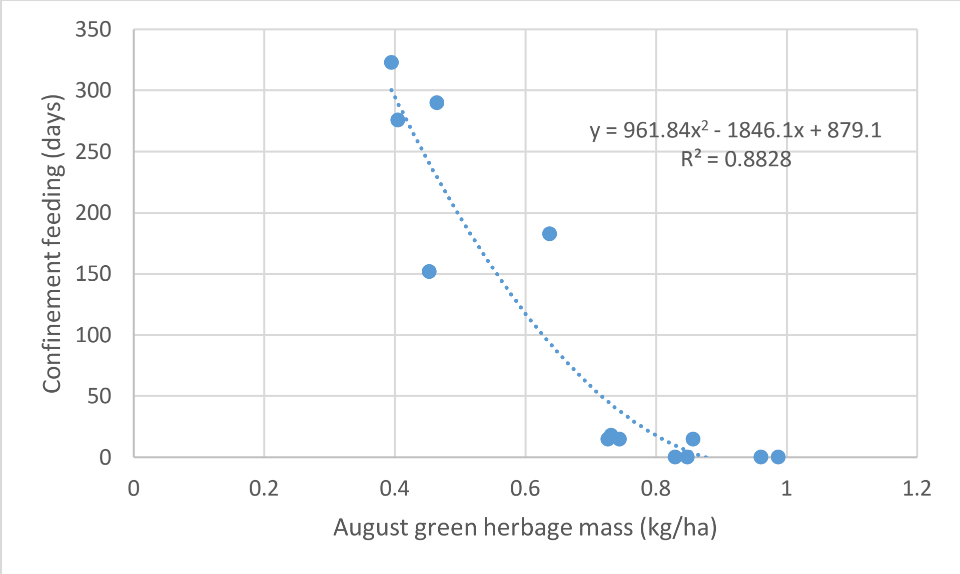

Figure 3.3.5.3. The green herbage mass in August (Instances where green herbage mass was < 1 t DM/ha) compared to the average days of confinement feeding.

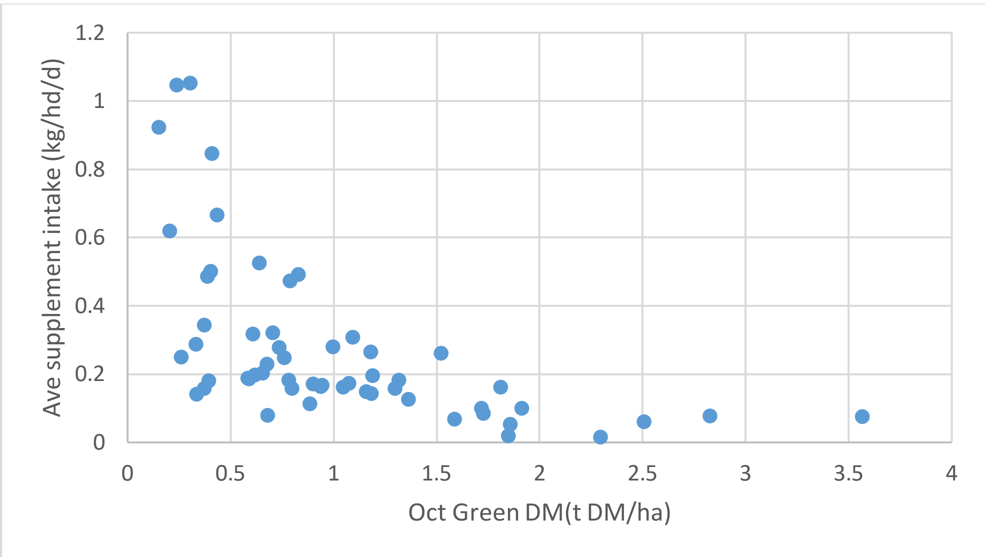

Figure 3.3.5.4. The green herbage mass in October compared to the average intake of supplement (kg per head per day) from November to February for a grazing system stocked at 0.25 ewes per ha at Balranald predicted using the SGS pasture model.

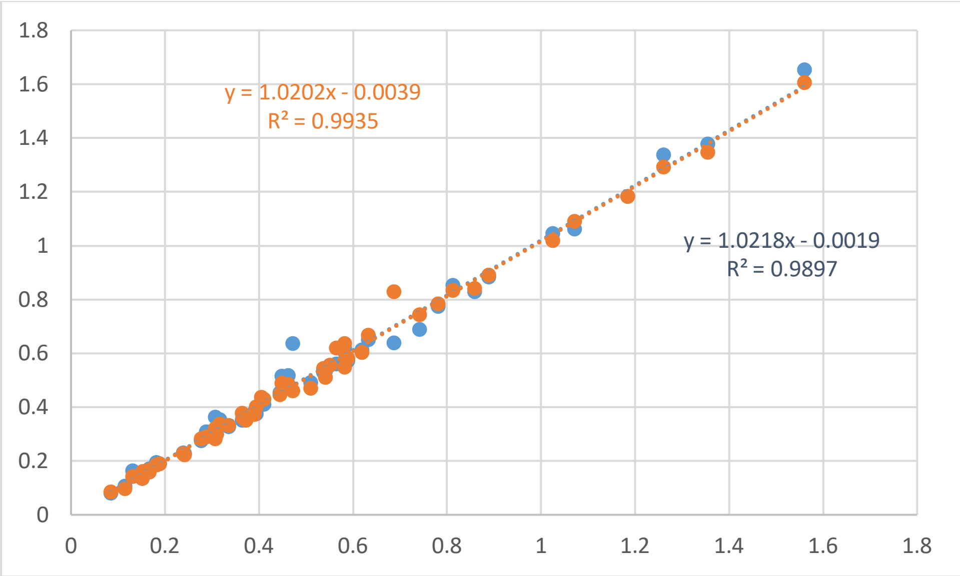

Figure 3.3.5.5. Comparison of January green DM between June lambing with lambs sold at 50 kg (blue) and April Lambing with lambs sold at 50 kg (red) compared to the base scenario of June lambing and lambs sold 1 November.