final report

Project code: B.GOA.0122

Prepared by: B. Cowled, S. Banney (Grazserv) and E. Patterson (Eulo Goat Depot)
Ausvet Pty Ltd

Date published: 18 May 2018

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Measurement of Rangeland Growth Rates

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

This project investigated the growth rates of rangeland goats and the potential gross margin of supplementary feeding.

This trial extended over 2 seasons (2016-2018). Goats were grazed normally on pasture and browse. Goats in half the paddocks received supplementary feed (lupins or pellets). Weight data was recorded at induction and every 4-8 weeks. In the 2016-2017 season, 638 goats were recorded for 3-6 months (3 146 goat months) across four sites (Dirranbandi, Eulo, Kingaroy and Warwick). In the second season, 450 goats were recorded for 4-6 months (2139 goat months), across three sites (Dirranbandi, Eulo and Warwick). Growth rates increased with the level of supplementary feeding with commercial pellet supplemented goats growing at 92g/day gain compared to 81g/day for non-supplemented goats. During the drought affected lupin trial (2017/2018), supplemented goats achieved a daily gain of 70g /day compared to 32g/day for the non-supplemented goats.

Gross margin analysis compared drought and non-drought, supplementary and non-supplementary feeding and compared goats against self-relacing dorper and merino sheep enterprises (wool and meat). Supplementary feeding produced profitable gross margins in drought years, but not in good seasons. This is of course subject to the quality and volume of feed in the paddock, prices received for stock sold and the cost of feed bought in. Goat gross margins were comparable to merinos and dorpers on a per hectare basis.

Executive summary

Introduction

Australia's rangeland goat industry originated as a pure wild harvest option in extensive pastoral regions. Over time there has been progressive interest in value adding retained young, underweight animals and growing them out in fenced paddocks as opposed to simply releasing them to roam wild again. There is a lack of rigorous data describing growth rates for rangeland goats under Australian conditions and a lack of data on options and expected growth rates if these animals are retained and fed supplemental feed. The objectives of this work were to investigate growth rates of rangeland goats and the potential benefit of supplementary feeding using gross margins.

Methodology

The goats used in the study were all small harvested rangeland goats between 13 and 20 kg.

Five study sites were used during the trial, including at Eulo (near Cunnamulla), Kingaroy, Dirranbandi, Warwick and Griffith (later removed).

All goats were grazed normally, receiving both pasture and browse. In addition, goats in half the paddocks received supplementary feed – either grain-based pellets (2016/17) or chopped lupins (2017/18).

Goat growth data was recorded by individually weighing goats at induction and every 4-8 weeks throughout the trial period. Goats were weighed as soon as practical after yarding, but after a one-month acclimatisation period on farm.

Analysis of growth rates consisted of basic descriptive statistics and linear mixed effects modelling (LMEM) which related weight and supplementary feed. The linear mixed effects modelling was applied to the natural log transformed goat weights as the response. The log transformed initial weights were treated as a covariate.

Gross margin comparisons were made between goat growing and Merino Sheep (wool and meat) and Dorper self-replacing flocks using published NSW DPI gross margin tools. For goats, real data was used, including growth rates, feed costs, averaged carcass values and two goat grow-outs per year.

Results

<u>Growth rates and effect of supplementary feeding</u>

The growth rate of goats was observed to increase with the level of supplementary feeding resulting in a 1.6kg benefit for the cereal based pellets. This equated to a 92g/day gain for the supplemented goats compared to 81g/day gain for non-supplemented goats.

In the lupin trials (2017/2018- all sites drought affected) there was a marked difference between the final weights of the supplemented (27.0 kg) and non-supplemented goats (21.8 kg) or 70 g/day for the lupin fed goats, averaged across all feed levels, compared to an average daily gain of 32 g/day for the non-supplemented goats.

Modelling of growth rates and supplementary feeding

Three models were implemented.

- Model 1 related treatment to weight gain over time.
- Model 2 extended Model 1 by including weather data for the preceding 30 days before a goat was weighed to attempt to control confounding variables associated with weather and pasture growth.
- Model 3 considered sex of goats. Males grew faster than females under all scenarios for at least the first 4 months (120 days) of growth in the trials.

Gross Margin Analysis

On a per hectare basis, Merino Sheep (self-replacing, wool and meat sales) had the highest gross margins ($12.21/ha). However un-supplemented goats ($11.85/ha) and Dorpers ($10.54/ha) were close to Merinos in terms of gross margins.

In most scenarios (not including drought), supplementary feeding led to smaller gross margins. Lupin supplementation of goats when drought was present lead to larger gross margins than un-supplemented goats, albeit at small gross margin of $1.70 per hectare, or a profit of $6,792 per 1,000 goats (cf. $1.06/Ha for un-supplemented goats).

Key messages

Supplementary feeding of rangeland goats can be profitable during drought conditions and allows stock to reach their sale weights earlier, thus ensuring more feed for the remaining herd.

Supplementary feeding should be generally avoided when conditions are reasonable. However, each situation needs to be assessed on its merits. For example, feed would need to be cheap and goat prices would need to be very good to make supplementary feeding profitable during good seasons.

Both Pellets and lupins were highly desirable to goats, consumed readily and led to weight gains. Lupins were much less expensive. Pellets flowed more easily in feeders than chopped lupins which tended to block feed shutes. Whole lupins are therefore preferable to chopped lupins.

Growth rates of +80 g/day are possible in un-supplemented goats when conditions are favourable.

Males grow faster than females.

Goat health in higher rainfall conditions can be compromised at high stocking densities by internal parasites. Great care is required to manage parasites.

Table of contents

1 Background

Australia has a large population of naturalised goats (*Capra hircus*), introduced by Europeans during settlement. These have been estimated to number several million goats (e.g. 2.6 million in 1995) and are predominantly distributed in the semi-arid rangelands of Qld, NSW, South Australia and Western Australia (Parkes, Henzell, & Pickles, 1995). However, more recent aerial surveys compiled for MLA estimate at least 5.8 million goats are present in NSW alone (Trudy Atkinson, NSW DPI, unpublished data), indicating this is an under-estimate. These goats are referred to as rangeland goats by the goat meat industry.

Australia is the world's largest exporter of goat meat. About 90% of Australian goat meat production is derived from Australian rangeland goats with a smaller contribution from Boer and other breeds. The Australian goat population is small by global standards, representing less than 0.5% of global goat populations, and global goat meat volume represents only 2% of total global meat inventory. However, goat meat demand is continuing to grow. The largest markets for goat meat exports are the USA and Taiwan and in recent years goat meat exports from Australia to China have rapidly expanded. There is also a gradual increase in the domestic market for goat meat as a low fat, healthy protein supply, especially for recent Australians who consume goat meat for cultural reasons. Goat meat exports were worth $257 million in 2017 (Araya et al., 2017). There is also a small but steady demand for live goat exports, mainly to Malaysia.

Australia's rangeland goat industry originated as a pure wild harvest option in extensive pastoral lands. Under a pure harvest operation those animals that exceed processing liveweight specifications (>24kg liveweight) and that are fit to transport are shipped for processing and animals that do not meet specification are released.

Over time there has been progressive interest in combining harvest operations with increased management intervention and breeding of rangeland goats to add value and increased sustainability and reliability of turn off for goat producers. An important component of this value adding has been retaining young, underweight animals and growing them out in fenced paddocks as opposed to simply releasing them to roam wild again.

There is a lack of rigorous data describing growth rates for rangeland goats under Australian conditions and a lack of data on options and expected growth rates if these animals are retained and fed supplemental feed. This information would be very useful for producers planning integrated operations that may include managed grow-out of rangeland goats to ensure cost-effective and reliable supply of quality animals to meet market requirements.

The goat industry and MLA have addressed this need in a systematic manner. In early 2015 a research report was produced that incorporated a literature review of factors affecting growth in goats and a design protocol for field studies to measure and describe growth rates for rangeland goats under Australian conditions (Alemseged & Atkinson, 2015a, 2015b). This report was used to guide the methodology of the current project.

This report describes the research conducted to investigate growth rates of rangeland goats, the potential benefit of supplementary feeding of rangeland goats and gross margin analysis that occurred between 2016 and 2018.

2 Project objectives

Stage 1: Produce a final protocol and detailed budget for field studies that describe the growth of rangeland goats under a combination of different growing conditions and with and without nutritional supplementation.

Stage 2: Implementation of the agreed protocol with collaborating producers at five sites to measure growth rate in rangeland goats over a 12-month period.

Stage 3: Completion of an enterprise comparison of a goat grow-out operation to a self-replacing Dorper enterprise (using gross margins analyses and comparing rangeland condition) and other regionally relevant enterprise choices, where possible

Note, by request from MLA, objective three was modified. Instead the gross margin analysis concentrating on Dorpers was modified and now also includes a merino sheep enterprise.

Industry was interested in the following questions being answered:

- What growth rates can be expected from growing out of underweight rangeland goats with and without supplementation?
- Does supplementation improve weight gain in rangeland goats?
- What is the genetic growth potential of Australian Rangeland goats?
- How does a goat enterprise compare with a Dorper enterprise under rangeland conditions?
- How does a goat production system influence rangeland condition?

It should be acknowledged that the last three points are difficult to address in full given the budget, timeframe and method of the trials.

3 Methodology

3.1 Goats

The goats used in the study were all harvested rangeland goats, the majority from the Eulo goat depot i.e. they did not originate from the properties on which the research was conducted. The key criteria for inclusion was that goats weigh between 10-24kg and were rangeland goats. Goats were marketed after 3-6 months of growing when they reached a commercially appropriate size for sale for the export market.

Randomisation occurred to balance groups to prevent confounding. At every site goats were randomised to a supplemented or un-supplemented group using a systematic random allocation of goats to one of two groups as they presented down a race at site induction.

Goats were individually identified with an electronic RFID tag and a high visibility management tag to allow regular sorting of goats if they moved independently to another paddock.

3.2 Study design

3.2.1 Pre-project study design

The project was pre-designed by NSW DPI (Alemseged & Atkinson, 2015a). See Appendix 1. This design was the TOR for the project as stakeholder consultation, MLA approval and statistical planning had been considered in the design.

The study design was a randomised block design, with paddocks within a property randomly assigned the experimental treatment of supplementary feeding or no supplementary feeding. Individual goats were the experimental unit, with goats randomly assigned to each paddock. This allowed estimation of growth rates and the effect of supplementary feed.

The variables can be summarised as:

- Treatment variable: Supplementary or no supplementary feeding with grazing
- Dependent variable: Weight gain (every 4-8 weeks)
- Confounding variables: Initial body weight, sex, pasture parameters (% greenness and dry matter yield per hectare at stocking), weather data (rainfall and temperature), drought indices, the amount of supplementary feed consumed and site.

3.2.2 Modifications to existing design

Some challenges with the pre-approved design were evident. These were addressed on an *ad hoc* basis as they arose. These included:

- Maintain goats for 12 months

The original trial protocol included that goats be maintained for 12 months on the commercial properties. No producers agreed to this requirement and so it was not possible to implement. Producers insisted they needed to market goats by approximately 6 months. Instead the protocol was changed such that goats were maintained for 3-7 months before being sold and two groups of goats were trialled at each property to enable 12 months of data to be collected.

In other words, the original trial design called for 300-320 goats to be maintained at 4 sites for 12 months (i.e. 1200-1280 goats). Instead, two groups of goats were maintained on each property for 3-7 months each for a total of 638 goats and 450 goats (1088 goats). An additional 280 goats were enrolled in the trial at Eulo, but these paddocks of goats were closed after two months when the site was destocked due to drought.

- Management input at the producer level was onerous

The requirement for monthly weights on all individual goats was onerous for producers, especially western producers with large properties that required aerial mustering.

This had several effects, most notably that most producers refused to participate in the project. For example, more than 30 producers and industry representatives were contacted to participate in the project, and most refused, citing that they were unable to devote enough time and resources to the project.

Therefore, some flexibility in the frequency of weighing goats was afforded to producers to enable participation. For example, some producers weighed goats every 6-8 weeks and were therefore able to participate.

Careful searching enabled the enrolment of 5 properties. Not all sites were ideal, but a compromise was made to ensure at least 4 properties were available (as specified in the study design).

- Replication at the paddock level (per site)

Replication of paddocks (4) per site was not possible, especially in eastern sites (high rainfall, smaller size farms). For example, three possible eastern high rainfall properties were potentially available to meet the requirement for an eastern site (Glen Innes, Warwick and Inverell), but no property could provide 4 paddocks as required. Instead the Warwick site was included and could provide two paddocks.

- Control of confounders at site level

The study design stipulated 4 paddocks per property and 4 properties (blocking) to control nuisance variables (i.e. confounding by environmental variables such as differing paddock soil fertilities, pasture availability, local climate conditions during the feeding trials, among others). This design was followed, albeit with two paddocks per site. However, it was found that these confounding factors were relatively homogenous across paddocks within a property, and hence variability in these factors was distributed largely at site level, not paddock or goat level.

The original intention was to use economic optimisation of the gross margin analysis to determine an optimal supplementary feed rate. However, the fact that feed rate was confounded with property (as in practice only one feed rate was assigned to each property) meant that the classic sigmoidal (or cubic) growth response to feed rate required for the optimisation could not be estimated. Consequently, traditional spreadsheet gross margin analyses were largely relied upon to provide conclusions as to the profitability of growing-out goats.

- Funding

Competitive funding principles and funding rules resulted in a marginal budget. For example, fencing and expensive weighing equipment were required at properties to enable their participation, but resources (marginal resources) and funding rules (no capital expenditure) ruled out some properties. This limited the number of paddocks and sites available. As a compromise solution, some funding such as temporary fencing was provided to enable the trial to proceed (e.g. Dirranbandi and Warwick).

- Weather conditions

Weather conditions were poor during the trial across the sites. In the first year flooding delayed the start of the trial at some locations (e.g. Dirranbandi). In the second year drought impacted the trial. Drought caused delays and reduced carrying capacity. Larger properties (e.g. Eulo) were able to stock additional paddocks. However, in two consecutive years, these paddocks were destocked early due to drought conditions, thereby resulting in the loss of the data from those paddocks.

3.3 Study sites

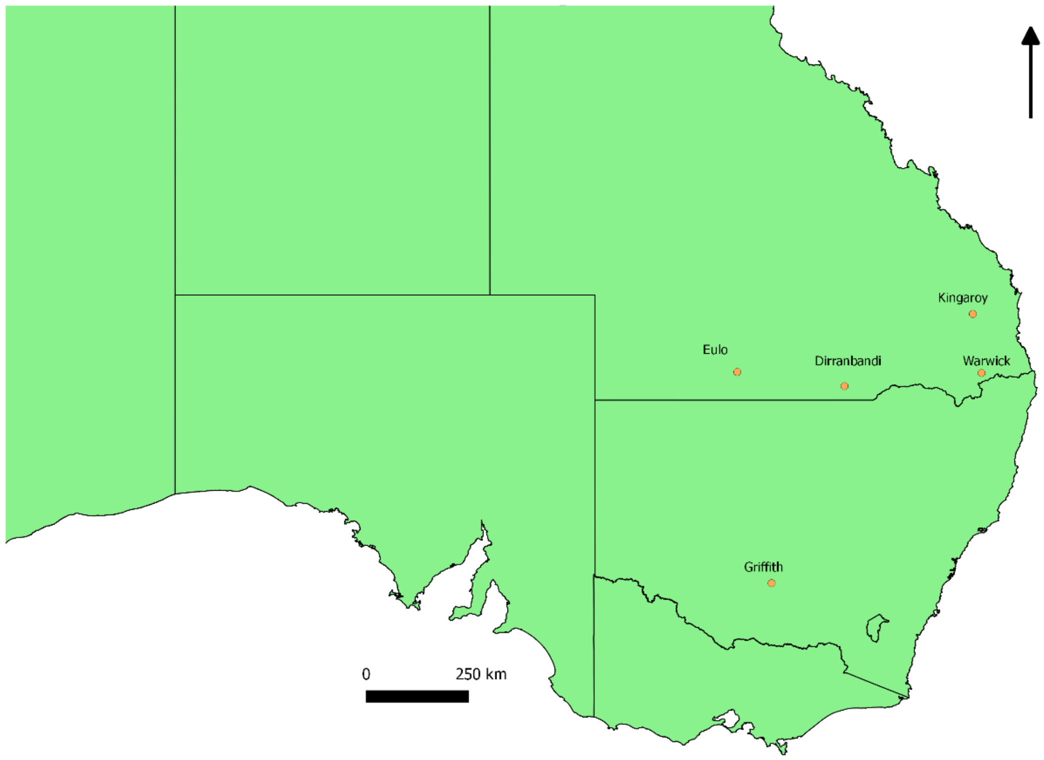
Five study sites were used during the trial. Please see

Table 1 for a brief description of the sites, data collection dates and goat numbers. Figure 1 is a study site location map.

Table 1: Study sites, start date and challenges.

Location	**Supplementary feed**	**Dates where goats stocked**	**Number of goats**	**Other comments**
Eulo (Springvale)	Pellets	16/8/16 to 20/12/16	175	This western Qld site was affected several times by drought but provided good data.
Eulo (Springvale)	Lupins	15/9/2017 to 18/01/2018	166	
Dirranbandi	Pellets	14/10/16 to 25/02/17	161	Mixed farming site (Qld), affected by floods and drought.
Dirranbandi	Lupins	29/05/2017 to 1/10/2017	160	
Kingaroy	Pellets	31/8/16 to 26/11/16	160	Site operational for part of trial period only due to drought.
Warwick	Pellets	9/7/16 to 28/1/16	140	Eastern higher rainfall site. Affected by drought.
Warwick	Lupins	15/7/2017 to 20/1/2018	124	
Leeton	NA	NA	160	Site closed early as unable to comply with study design (fencing/separation of treatment groups).

Figure 1: The study sites used during the goat growth project in Eastern Australia.



3.4 Supplementary feed used

All goats were grazed normally, receiving typical pasture and browse.

In addition, goats in half the paddocks received supplementary feed. The goats in the other half of the paddocks received no supplementary feed. Goats were randomly allocated (systematic random allocation) to either group (supplementary or no supplementary feed).

In most locations (Eulo, Kingaroy, Dirranbandi), goat treatment groups swapped paddocks with one another each month to ensure that the pasture available to each was comparable. Therefore, individual paddock conditions within a site could not confound the study.

In the first half of the trial, the supplementary feed used was a commercially prepared pellet by Ridley Agriculture. The second half of the trial used chopped lupins.

Energy concentration between the two diets was similar with a concentration of 11.6 MJ/kgDM for pellets and 12.1 MJ/kgDM for lupins. Protein was higher for the lupins. See Table 2 for a comparison and Appendix 2 and 3 for more detailed information (analysis of lupins and pellets).

Table 2: Nutritional composition of pellets and lupins used in trial.

Feed parameter	Lupins	Commercial pellets
Protein*	31.6	17.4
Fat*	4.7	4.1

Ash*	3.7	8.1
Crude fibre*	16.0	32.3
Dry matter*	91.8	100
Nitrogen (free extract)*	39.1	-
Metabolisable energy (MJ/kg DM)	12.1	11.9
Moisture (air)*	8.1	12.2

*%(w/w)

The pellets were comprised of:

- wheat fines
- sorghum fines
- canola meal
- dried distillers grain
- legume hulls
- molasses
- various minerals and vitamins
- monensin, included for use as a coccidiostat.

Pellets and chopped lupins were administered via a commercial feeder (e.g. Advantage Feeders (http://advantagefeeders.com.au/3800hd/)). The weight of pellets and lupins administered over time to the total goats at each site was recorded. The mean weight in grams of pellets consumed per goat was calculated for each site.

Error! Not a valid bookmark self-reference. presents the number of goats used for each part of the trial (lupins or pellets).

Table 3: The number of goats and stocking dates for trial goats in the trial.

Site	Dates of data collection	Number of goats
Eulo (Springvale)- Pellets	16/8/16 to 20/12/16	175
Eulo (Springvale)- Lupins	15/9/17 to 18/01/18	166
Dirranbandi – Pellets	14/10/16 to 25/02/17	161
Dirranbandi- Lupins	29/05/17 to 1/10/17	160
Kingaroy- Pellets	31/8/16 to 26/11/16	161
Warwick- Pellets	9/7/16 to 28/1/16	141
Warwick- Lupins	15/7/17 to 20/1/18	124
Total	**9/7/16 to 20/1/2018**	**1,088**

3.5 Measurements

3.5.1 Goat weights

The main outcome measure was the weight of goats to a tenth of a kilogram. Goat growth data was recorded by individually weighing goats at induction and every 4-8 weeks throughout the trial period.

Goats were weighed on electronic scales and had their weights and identification number automatically recorded at every weighing session. They were weighed with commercial weighing equipment. For example a Gallagher weigh crate (https://am.gallagher.com/au/products/weighing-and-eid/platforms-and-crates/SG05798) with 600kg load bars, HR5 data recorder and W810 indicator. Goats were weighed as soon as practicable after yarding and fasting in yards was not practiced. All goats were present on site for at least one month before inclusion in the trial.

Data was electronically exported as an Excel spreadsheet and imported into R for analysis (https://www.r-project.org/).

In addition, the sex, starting weight, site and date were recorded for each goat each time they were weighed. Kids that were born were included in outcome for the group of goats in the paddock. That is, the total weight of kids borne was divided by the number of goats in the paddock and added to each goat in the paddock as 'weight gain'. This was a pragmatic solution to account for kid production, as it was not possible to attribute kids to a doe, but this method allowed the yield of kids to be included in analysis.

3.5.2 Collection of data on confounders

Pasture condition

Pasture condition information at induction of a group of goats was recorded. The information collected included the yield (kilograms of dry matter/ha) and greenness (% green). The yield included ground cover and the edible browse layer that goats also consume. These were calculated by the use of Botanal (Tothill, Hargreaves, & Jones, 1992) and Stocktake (http://www.stocktakeplus.com.au/faqs/how-do-i-assess-pasture-condition/).

Botanal is pasture visual assessment technique developed by CSIRO. Using permanent transects, data recorded includes species present, dry matter yield, ground cover percent, percent green and percent unpalatable. The collected data can be objectively analysed.

Stocktake is another visual assessment technique developed by QDAF. This approach uses visual assessment of soil and pasture condition, tree density along with site photos. Using the comparative branch technique, dry matter yield of top feed is also estimated.

Weather data was also assumed to be a proxy for pasture condition. This was collected from the Australian Bureau of Meteorology. This consisted of total rainfall and mean maximum temperature per site. The data was gathered from the nearest BOM observatory, the furthest distance being the distance between Eulo and Cunnamulla (approximately 63kms). Weather variables were collected for modelling and included total rainfall in the last 30 days, mean maximum temperature over the last 30 days, mean minimum temperature over the last 30 days, the Keech-Bryam drought index measuring a cumulative soil moisture balance (Alexander, 1990), and a drought factor index also measuring a cumulative soil moisture balance (Keetch, Byram, & eorge M. . Res. Pap. SE-38. Asheville, 1968).

All covariates were scaled for purposes of model estimation.

3.6 Statistical analysis

3.6.1 Description, modelling of growth curves and effect of supplementary feeding

All data was imported into R (R_Core_Team, 2018) where data manipulation, error checking and analysis occurred.

Analysis consisted of basic descriptive statistics and linear mixed effects modelling (LMEM). The linear mixed effects modelling was applied to the natural log transformed goat weights as the response (glmmTMB library in R; (Brooks et al., 2017; Magnusson et al., 2017; R_Core_Team, 2018)). The log transformed initial weights were treated as a covariate. This thus expresses the output of the model as the proportional increase in weight from the start weight.

The linear mixed effects models considered as key explanatory variables the following:

- The type of supplement supplied (pellet, lupins or no supplement)
- A cubic, non-linear function of time since start of the trial to represent a growth curve (alternatively, a logistic-type function of time could have been applied, however, in some trials weight loss was observed during drought conditions)
- A linear function of feeding rate (a single feeding rate was assigned to each property, and hence is confounded with property; ideally the feeding rate response curve would be logistic or similar)
- Weather metrics: total rainfall in the last 30 days, mean maximum temperature over the last 30 days, mean minimum temperature over the last 30 days, the Keech-Bryam drought index (KBDI) measuring a cumulative soil moisture balance (Alexander, 1990), and a drought factor index (Keetch et al., 1968) also measuring a cumulative soil moisture balance
- Sex of animal
- Initial weight (log value applied as a covariate to express the untransformed weight through time as a proportion of the initial weight. This was designed to account for differing initial weights in the model while minimising model complexity)
- Up to three-way interactions between the above variables were considered
- All the continuous valued variables were normalised by subtracting the mean value and dividing by the standard error of the variable.

Three core models were then considered for the growth curve modelling, depending on which covariates were included with the growth response over time:

- Model 1

Model 1 related the treatment (i.e. lupins or pellets verse pasture) to weight over time. The property on which a trial was conducted was treated as a fixed effect, with the four properties treated as separate levels of a ‘location’ categorical (or factor) variable. This model may be simply expressed as:

$$\log_e Weight_{it} \sim (t + t^2 + t^3) * Supplement * Feed + Location + \log_e InitialWeight_{it} + \varepsilon_i + \varepsilon_{it}$$

where i is the identity of the goat, t is time since the start of the trial, '$*$' indicates an interaction between two or more terms, ε_{it} is the residual error, and ε_i refers to an animal specific random effect with the repeated weighing of each animal. Feed and time are scaled (z score).

Note that the growth response through time is modelled as a cubic polynomial of time (i.e., $(t + t^2 + t^3)$). As with Model 2 and Model 3 the residuals were assumed to be normally distributed, with no strong evidence in tests for over-dispersion of the residuals (through a maximum likelihood ratio test with a comparative negative binomial model). The inclusion of random effects in the model was also tested through a maximum likelihood ratio test.

- Model 2

Model 2 substitutes the weather variables and initial pasture condition variables for the location factor. Moreover, the descriptor variables of weather also act as proxies for pasture to identify the prevailing conditions at each sampling date within a location. Hence, weather variables were also included to better control for the effects of pasture growth than irregular pasture assessments as they were immediate and continuous throughout the study period. Model 2 is therefore a generalisation of Model 1, allowing the extrapolation of the model to other properties using environmental descriptors, at least in principle. Formal testing of these property and time descriptive variables via AIC minimisation determined the final model form.

A key feature of Model 2 is that it models feed rate for each supplement as a linear term interacting with the growth response. Ideally, higher order polynomials would be included for feed rate (i.e., growth as a function of feed rate would follow a logistic-type curve). However, these higher order terms were excluded due to a failure in convergence of the model fitting. Hence, the final form of Model 2, following a stepwise selection of terms via the Akaike's Information Criterion (AIC), was expressed as:

$$\log_e Weight_{it} \sim t_i + t^2 + t^3 + SupplementType * FeedRate * t + \log_e InitialWeight_{it} \\ + KBDI_t + TemperatureMin_t + TemperatureMax_t * t + \varepsilon_i + \varepsilon_{it}$$

The term t_i is an animal specific random effect applied to the linear term estimated for time t. Due to no replication within the paddock level then paddock identity was excluded as a random effect. Property identity was also excluded, as it was confounded with the $SupplementType * FeedRate$ interaction.

- Model 3

Model 3 considers sex of the animal. Model 3 was then used to provide a coarse plug-in adjustment for growth rate depending on sex for models 1 and 2 if, for example, a sex adjustment is required as part of an enterprise gross margin calculation.

R code outlining these models is included as Appendix 4.

3.6.2 Gross Margin Analysis

TOR specified a comparison between a self-replacing Dorper enterprise and a rangeland goat grow-out enterprise. However, a request was made by MLA to add to the comparison and instead use a common regionally relevant enterprise in addition to the Dorper enterprise. A merino self-replacing enterprise was added. All comparisons and gross margin modelling were based on enterprises in south west Queensland, namely Dirranbandi which achieved the highest and lowest growth rates of all the sites in the pellet and lupin trials respectively.

- Spread sheet modelling

An Excel feed margin calculator developed by New South Wales Department of Primary Industries was adapted for use in calculating a gross margin per scenario (Anon., 2017).

- Scenarios modelled

The scenarios modelled in the gross margin analysis are represented in **Error! Not a valid bookmark self-reference.**. Essentially, these scenarios model goats, merino sheep and Dorpers. Goats are modelled under several scenarios, namely the pellet trial under favourable seasonal conditions (as occurred), the lupin trial under unfavourable seasonal conditions (as occurred) and a simulated scenario where lupins were supplemented under the same favourable seasonal conditions as occurred in the pellet trial. Sensitivity analyses occurred for each of the goat scenarios where the growth rates achieved and prices received for goats varied. The following headings outline the assumptions in more detail, but the reader is referred to Appendix 5 for very detailed assumptions and the gross margin calculator.

<u>Merino sheep</u>

A self-replacing 20-micron merino sheep enterprise in south west Queensland was modelled. This model accounted for income from both wool and sheep sales (ewes, rams, weaners and hoggets). The flock size was 1,000 ewes and it was assumed weights were 60kg (larger western sheep). It was assumed that each ewe had a dry stock equivalent (DSE) rating of 3. This was assumed as we assumed the DSE equivalent in the most feed restricted time of the year(McDonald & Orchard, 2018) (i.e. a ewe with lambs at foot in the winter). Average sale prices ($ per kilogram of carcass weight) were modelled at $4.40 (ewes) to $6.20 (weaners). Wool yield was estimated at 5 kg/head with a price of $7.50 (ewe lambs) to $16.00/kg. A stocking rate of 0.25 DSE per hectare was assumed.

Merino sheep were modelled under two scenarios, lupins used as a supplement to all stock for 70 days ($350/tonne) and no lupins.

<u>Goats</u>

A grow out goat enterprise was modelled based on Dirranbandi growth rates. This model accounted for income from two grow out periods of 5 months each, for each year of production so that it was directly comparable to year-round Dorper and Merino enterprises. The flock size was 1,000 goats. It was assumed that a goat had a DSE rating of 1 and a stocking rate of 0.25 DSE per hectare. This was assumed as goat DSE vary from 0.75 to 1.5 (Anon., 2018). Whilst most goats were weaners (less than 1 year old with a DSE of 0.75) a proportion of them were breeding and older (DSE 1.5). A slightly conservative estimate was made (i.e. DSE of 1), and it is possible that a slightly improved gross margin per DSE would be possible if the DSE was over-estimated. Average sale prices ($ per kilogram of carcass weight) were modelled at $5.11.

Goats were modelled under three scenarios. Two scenarios reflected actual data, the third scenario a simulated scenario. The first scenario modelled the good season where pellets/no pellets were fed. The second season modelled the poor (drought) season where goats received lupins/no lupins. The third simulated scenario used the 2016/2017 growth rates, but substituted lupins/no lupins for pellets to examine the cost of a cheaper food source when goats are growing optimally. In this third simulated scenario it was assumed that goats would achieve the same growth rate on lupins as was achieved for pellets.

Dorpers

The Dorper enterprise used a similar structure to the merino sheep enterprise, except that wool sales, and wool variable costs were not included. The flock size was 1,000 ewes. Replacement rams, cull and market sales were included. It was assumed that each ewe had a dry stock equivalent (DSE) rating of 3 and a stocking rate of 0.25 DSE per hectare. The same DSE rating was used as for merino sheep as research in semi-arid Australia indicates that merinos and Dorpers are equivalent for DSE (Alemseged, 2015). Average sale prices ($ per kilogram of carcass weight) were modelled at $4.40 (ewes) to $6.20 (weaners).

Dorper sheep were modelled under two scenarios, lupins used as a supplement to all stock for 70 days ($350/tonne) and no lupins.

- Economic optimisation

An optimiser was then added to the Excel feed margin calculator. The optimiser utilises the growth curves estimated in the modelling step, multiplies these by the costs provided in the feed margin calculator, and finds an optimal rationing period and feed rate. This solution is readily found where the marginal cost of providing extra rations, either in terms of the duration or volume of rationing, the marginal increase in sales resulting from the live weight gain attributable to that further investment in rationing is equal.

As a demonstration of feasibility Model 2 provides the growth rates that underpin the pricing of marginal benefit.

3.6.3 Assessment of rangeland conditions

Data on the yield of dry matter per hectare and species composition was collected before and after goat grazing (i.e. compared between 2016/2017 and 2017/2018 trial years). That is, data was collected before the 2016/2017 grazing and then again approximately 6 months later, after grazing was completed (before the second year of grazing began). Stocking rates varied by site between approximately 0.25 to 3.5 goats per ha.

Data on yield was compared between years with a linear mixed model that related the outcome of yield of dry matter against grazing by goats (yes or no) and the confounding effect of drought index. A random effect was included for site due to repeat measuring. The following model was implemented.

$$\log_e(Dry\ matter) \sim Goat\ grazing + Drough\ index + random\ effect\ (property)$$

Species composition data was not modelled as two sites had pasture that was too short for species assessment, meaning only two sites had data, too few points for regression modelling.

Several confounding factors remained uncontrolled (e.g. all sites had a prior unrecorded grazing history).

3.1 Animal ethics

Animal ethics approval was granted by NSW and Qld Departments. These included:

The Animal Care and Ethics Committee of the Secretary NSW Industry, Skills and Regional Development provided an Animal Research Authority certificate of approval (Trim16/406 Secretary's ACEC Meeting 174 21 March 2016).

The Community Access Animal Ethics Committee of Agriscience Queensland (Department of Agriculture and Fisheries) approved the project (SA 2016/03/551).

Each Department also registered Ausvet as an animal research organisation.

Table 4: Gross margin modelling scenarios

Scenario	Description	Major assumptions
Dirranbandi lupin trial (actual trial results)	Lupins c. no lupins in drought conditions	Dry stock equivalent: 1 Lupin cost: $350/tonne Lupin consumption: 190/day Time on supplement: 125 days Start weight: 18 and 18.5kg (no/lupins) Sale weight: 21.4 and 25.5kg (no/lupins) Growth: 56g/head/day (lupins) and 22g/head/day (no lupins)
Dirranbandi pellet trial	Pellets cf. no pellets in good seasonal conditions	Dry stock equivalent: 1 Pellet cost: $660/tonne Pellet consumption: 363g/day Time on supplement: 134 days Start weight: 12 and 13kg (no/pellets) Sale weight: 25.5 and 27kg (no/pellets) Growth: 112g/head/day (pellets) and 93g/head/day (no pellets)
Dirranbandi simulated lupin trial	Lupins cf. no lupins in good seasonal conditions Note: This simulation used 2016/2017 pellet growth rates and substituted lupins from 2017/2018 trial as a cheaper food source to enable gross margin calculations using a cheaper food source. The simulation assumes that growth rates achieved by lupins would be the same as pellets.	Dry stock equivalent: 1 Lupin cost: $350/tonne Time on supplement: 125 days Start weight: 15kg Sale weight: 25.5 and 27.5kg (no/lupins) Growth: 122g/head/day (lupins) and 93g/head/day (no lupins)
Merino sheep	A self-replacing merino flock that sells 20-micron wool and meat and supplements for 70 days per year (lupins). Note this data was simulated data by expert opinion and no field trials occurred.	NSW DPI Farm Enterprise Budget Series October 2017 (Anon., 2017) and see Appendix 5.
Merino sheep	A self-replacing merino flock that sells 20-micron wool and meat and does not supplement. Note this data was simulated data by expert opinion and no field trials occurred.	

Dorper meat sheep	A self-replacing Dorper flock that sells meat and supplements for 70 days per year (lupins). Note this data was simulated data by expert opinion and no field trials occurred.	
Dorper meat sheep	A self-replacing Dorper flock that sells meat and does not supplement. Note this data was simulated data by expert opinion and no field trials occurred.	

4 Results

4.1 Statistical analysis relating treatment and growth

4.1.1 Descriptive analysis

The trial examined the growth rates of goats over two seasons (2016-2017 and 2017-2018). In the first season (2016-2017), 638 goats were followed for 3-6 months (over 3 146 goat months) across four sites (Dirranbandi, Eulo, Kingaroy and Warwick). All goats received pasture and browse. In addition, half the goats received commercial goat pellets, equivalent to 1-2% bodyweight.

In the second season (2017-2018) 450 goats were followed for 4-6 months (over 2139 goat months), spread across three sites (Dirranbandi, Eulo and Warwick). All goats received pasture and browse. In addition, half the goats received chopped lupins equivalent to 1-2% body weight. No direct comparison occurred between lupins and pellets in the same year.

The growth rate of goats was observed to increase with the level of supplementary feeding. For the commercial pellet trial goats weighed 15.1kg on average at the start of the trial. At the end of the trial goats that received supplementary feed weighed 26.9kg, whereas non-supplemented goats weighed 25.1kg, resulting in a 1.6kg gain. This equated to a 92g/day gain for the supplemented goats compared to 81 g/day gain for non-supplemented goats.

The median starting weights of goats in the lupin trials was 16.6kg. There was a marked difference between the final weights of the supplemented (27.0kg) and non-supplemented goats (21.8kg) in the 2017-2018 lupin trials, with the supplemented goats having a final weight 7kg higher than the non-supplemented goats. This resulted in an average daily gain of 70g/day for the lupin fed goats, averaged across all feed levels, compared to an average daily gain of 32g/day for the non-supplemented goats. See Table 5 for a summary of the raw data.

Table 5: Median start and finish weights of goats in both treatment groups (supplemented and un-supplemented).

Trial	Group and time		Median weight (Q1-Q3) (kg)
2016-2017 Commercial Pellets	Start weight	Supplemented	15.1 (13.2-17.3)
		Un-supplemented	14.9 (14.8-17.0)
	Finish weight	Supplemented	26.9 (23.9-30.4)
		Un-supplemented	25.1(22.6-28.3)
2017-2018 Lupins	Start weight	Supplemented	16.6 (14.7-19.5)
		Un-supplemented	16.8 (14.8-18.9)
	Finish weight	Supplemented	27.0 (23.9-31.3)
		Un-supplemented	21.7 (19.5-24.0)

To control for the differential weather at the different properties and between years then a set of climatic variables were captured from the nearest BOM site to each trial site at each weighing time. Maximum daily temperature and minimum daily temperature were averaged over the previous 30 days, and rainfall was summed. Additionally, the Keech-Bryam drought index and related drought factor were computed to give an index value on the day of weighing. These drought indices are applied in fire management as a surrogate measure for the flammability of senesced vegetation and soil moisture, and account in part for the timing of rainfall events (Keetch and Bryam 1968, Alexander 1990). Both indices were initialised at their maximum value (full drought), starting on 1st January 2010, to allow sufficient burn-in for the calculation to lose sensitivity to the initial values. See Table 6.

Table 6: Summary of climate variables for the duration of each trial

Property	Trial	Rainfall (mean daily mm)	Maximum Temperature (mean °C)	Minimum Temperature (mean °C)	KBDI (mean)	Drought Factor (mean)
Dirranbandi	Pellet: 2016/17	1.11	36.3	20.8	97.9	8.17
	Lupin: 2017/18	0.23	24.4	6.4	145.2	10.1
Eulo	Pellet: 2016/17	1.35	28.8	15.0	55.0	7.53
	Lupin: 2017/18	0.70	34.2	20.1	168.5	9.46
Warwick	Pellet: 2016/17	2.66	24.3	9.6	17.3	5.34
	Lupin: 2017/18	2.33	26.6	9.9	70.2	8.06
Kingaroy	Pellet: 2016/17	1.11	26.7	10.6	60.5	8.09
	Lupin: 2017/18	-	-	-	-	-

Table 7: Summary of pasture productivity at start of each trial period.

The larger western properties were able to rotate equal sized goat groups each month between paddocks. Subsequently one pasture estimate is provided for each of the lupin and pellet trials. The Warwick site was unable to rotate goats between paddocks due to uneven mob sizes and different sized paddocks. Hence estimates are provided for treatment (pellets and lupins) and control paddocks.

Property	Trial	% Greenness	Kg dry matter per hectare
Dirranbandi	Pellet: 2016/17	29	591
	Lupin: 2017/18	2	404
Eulo	Pellet: 2016/17	14	454
	Lupin: 2017/18	~	200
Warwick (pellets)	Pellet: 2016/17	81	134
	Pasture	44	76
Warwick (lupins)	Lupin: 2017/2018	53	958
	Pasture: 2017/2018	61	774
Kingaroy	Pellet: 2016/17	62	566
	Lupin: 2017/18	~	~

4.1.2 Modelling

Model 1

Model 1 related treatment to weight gain over time. The model converged adequately and explained the majority of variability in the data (r^2=68.3). Figure 2 displays the growth curves of goats by site, treatment and time. The highest growth rates were observed at Dirranbandi in the pellet trial. Lupin treated goats at all sites grew faster and bigger than pasture fed goats during the lupin trial.

There was a significant relationship between supplementary feeding and weight of goats at the end of the trial (see Appendix 6**Error! Reference source not found.**).

Model 2

Model 2 extended Model 1 by including weather data for the preceding 30 days before a goat was weighed to attempt to control confounding variables associated with weather and pasture growth. A fixed weather scenario was assumed, defined by the rounded median of each weather parameter across both trial periods (i.e. pellets verse lupins). Model outputs indicted that supplemented goats still weighed more than un-supplemented goats. Pellet fed goats weighed more than lupin fed goats, unless lupins were fed at greater than 400g/day. Despite this, the response of lupin fed goats was much greater than for pellet fed goats, with a much larger increase in weight for lupin fed goats compared to control goats in the lupin trial than the pellet trial. It is possible there is some residual confounding in this comparison between trials.

See Figure 3 and Appendix 6.

Model 3

Males grew faster than females under all scenarios for at least the first 4 months (120 days) of growth in the trials.

See Figure 4 and Appendix 6.

Figure 2: Weight of goats by time, treatment group and location.

Un-supplemented goats weighed less at the end of the trial than supplemented goats. The early trial data (thin lines) is for the most part found above the late trial data, especially for the non-supplemented animals (dashed lines). Growth responses were largely consistent at Warwick (blue lines) but were more varied for Eulo (red lines) and Dirranbandi (black lines) in particular. Adjusted r^2 = 68.3%.

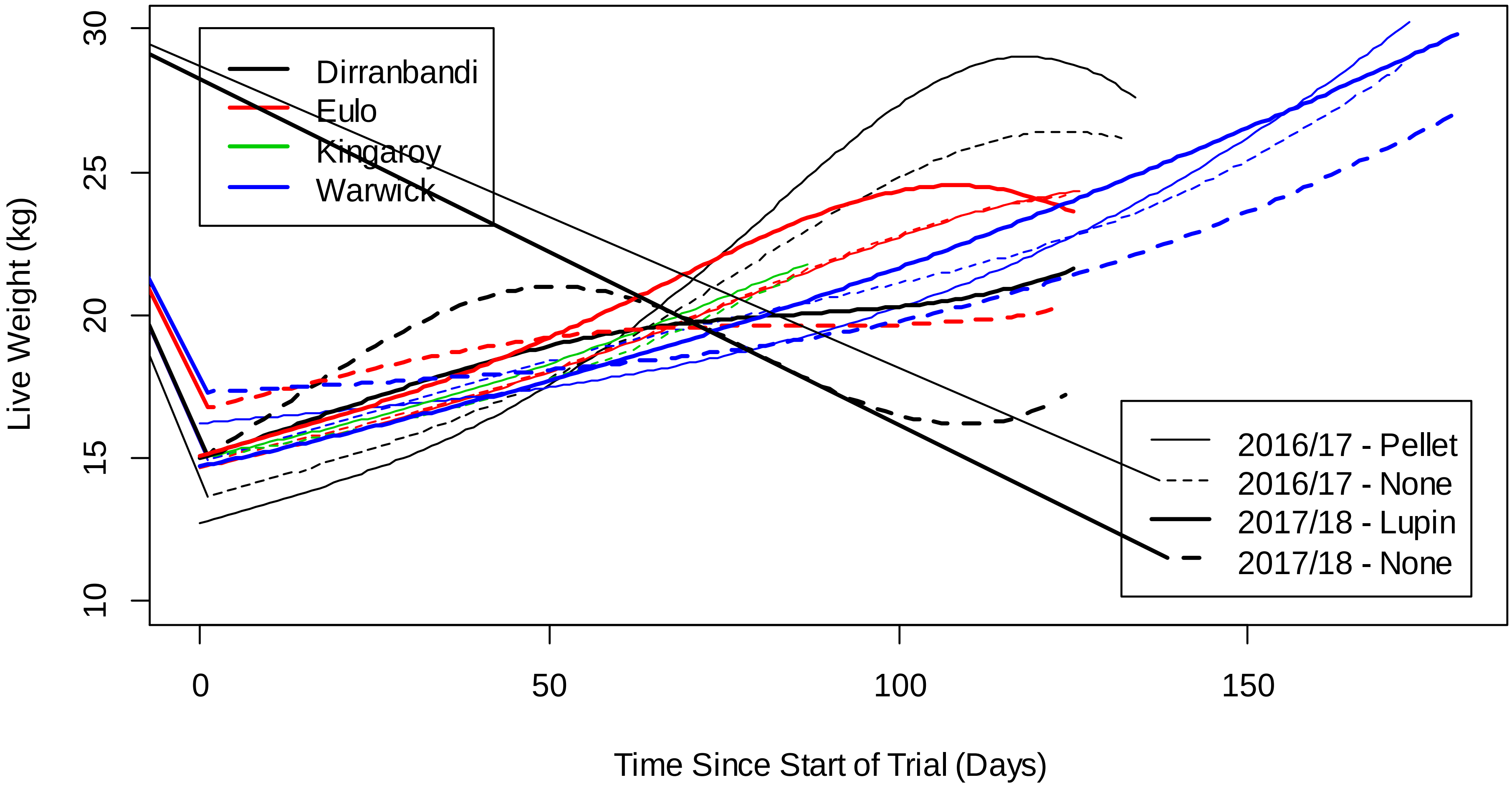


Figure 3: Model 2 growth curves for different feed rates and supplement types under a fixed weather scenario, defined by the (rounded) median of each weather metric across both the early and late trials (KBDI= 80, minimum monthly temperature = 12°C, maximum monthly temperature = 28°C, monthly rainfall = 40 mm).

Un-supplemented goats weighed less at the end of the trial than supplemented goats. The un-supplemented 2017/2018 goats grew more slowly than the un-supplemented 2016/2017 goats (drought). Pellet fed goats had greater weight than lupin fed goats except when the lupin feed rate was greater than 400 g/head/day. The response to lupins was greater, starting from a much lower baseline growth curve with zero feed, although this result may be confounded by the drought season experienced during the lupin trial

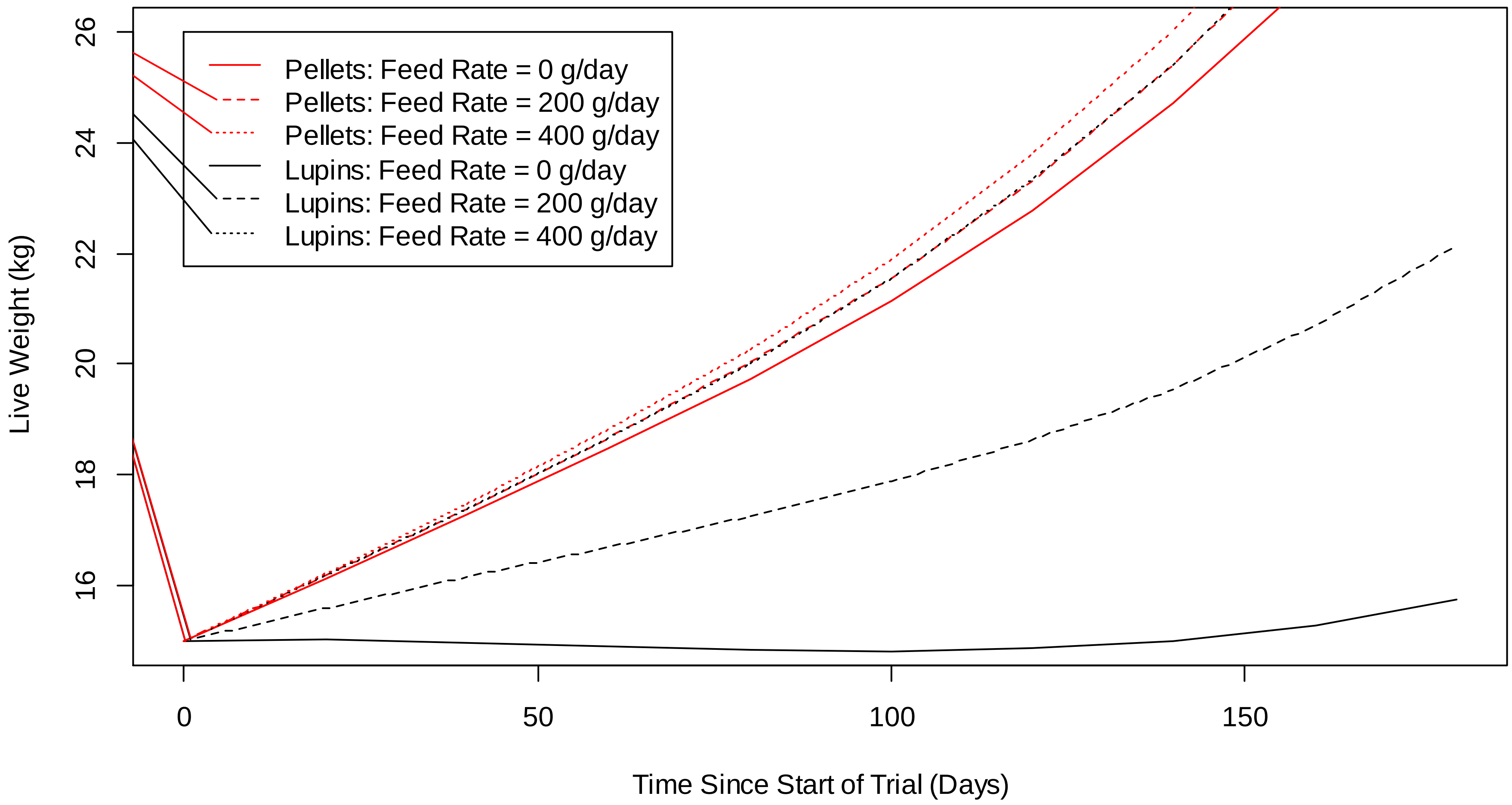
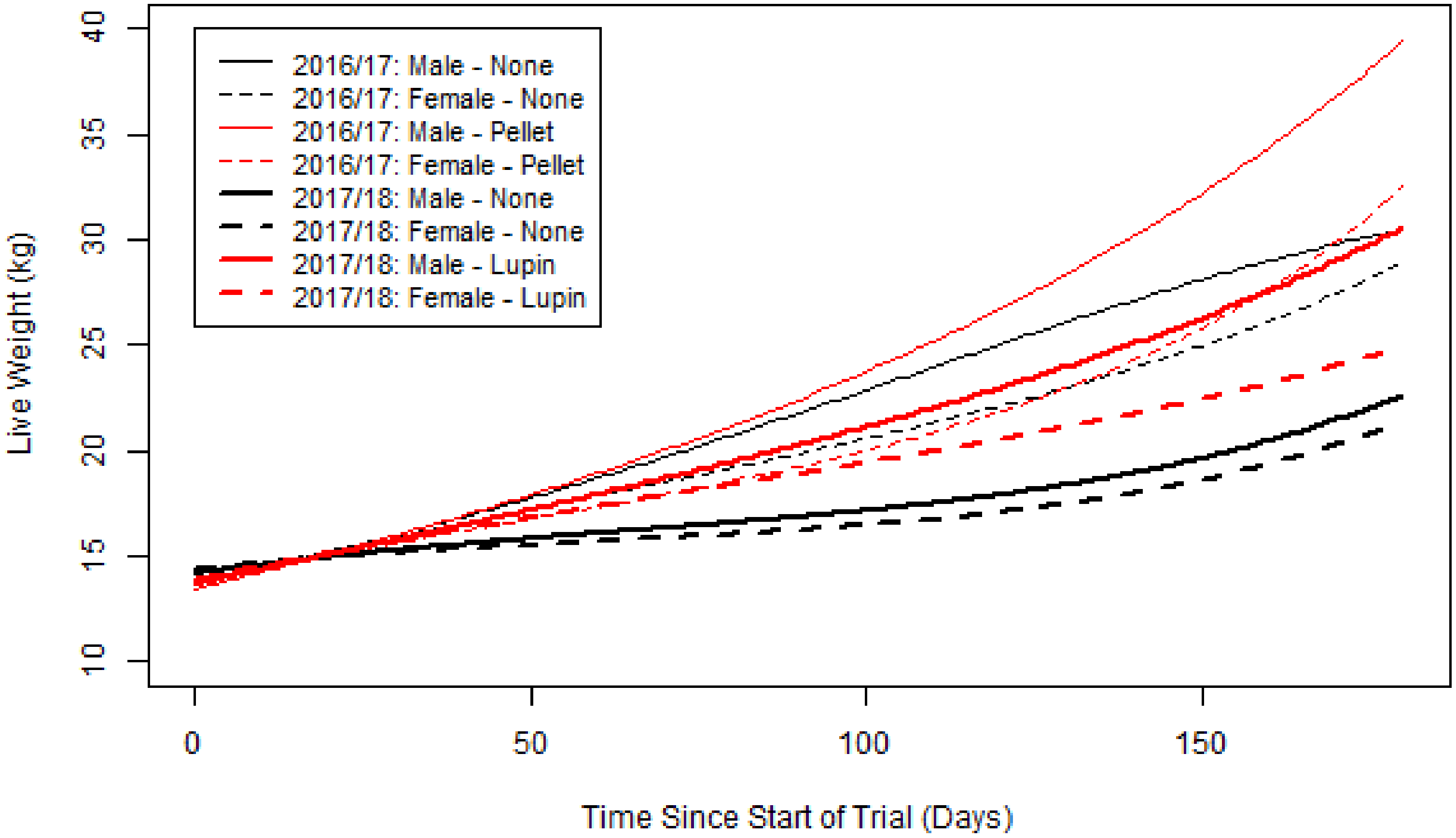


Figure 4: Model 3 growth curves for males and females at different feed rates (pellets at 363 g/head/day; lupins at 307 g/head/day). Growth rates of males are greater than those of females for the first 120 days at least.



4.2 Economic modelling

4.2.1 Gross margin analysis (spreadsheet modelling)

On a per hectare and yearly basis, Merino Sheep had the highest gross margins. However, in good seasons, where supplementary feed was not required, goats and Dorpers were similar to Merinos in terms of gross margins per hectare on a yearly basis.

In most scenarios, supplementary feeding and drought conditions lead to relatively smaller gross margins. Despite this, it is important to note that lupin supplementation of goats when drought is present still lead to positive gross margins, albeit at small gross margin of $1.70 per hectare, or a profit of $6,792 per 1,000 goats. This was a slightly larger gross margin (more profitable) than un-supplemented goats during drought.

It would be expected that lupin supplemented goats in a favourable year would lead to a relatively high gross margin of $9.53 per hectare, or a profit of $38,124 for two groups of 1,000 goats per year.

See Table 8.

Sensitivity analyses around the price of goats and lupin cost is presented in Table 9.

Table 8: Gross margins for various enterprises and goat growth scenarios in descending order of gross margin per hectare.

Scenario	**Supplementary feed type**	**Gross margin ($)**			
		Total gross margin	**Gross margin per head**	**Gross margin per hectare**	**Gross margin per DSE**
Merino sheep (no supplementary feed for 70 days)	No lupins	146 465	146.47	12.21	48.82
Dirranbandi pellet trial (actual trial results)	No pellets	47 388	23.65	11.85	23.65
Dirranbandi lupin trial (simulated*)	No lupins	44 460	22.23	11.12	22.23
Dorper sheep (no supplementary feed for 70 days)	No lupins	126 536	126.54	10.54	42.18
Merino sheep	Lupins for 70 days all sheep	124 258	124.26**	10.35	41.42
Dirranbandi lupin trial (simulated*)	Lupins	38 124	19.06	9.53	19.06
Dorper meat sheep	Lupins for 70 days all sheep	95 048	95.05**	7.92	31.68
Dirranbandi lupin trial (actual trial results)	Lupins	6 792	3.40	1.70	3.40
Dirranbandi lupin trial (actual trial results)	No lupins	4 224	2.11	1.06	2.11
Dirranbandi pellet trial (actual trial results)	Pellets	-6 338	-3.17	-1.58	-3.17

* simulated assuming favourable seasonal conditions using growth rates from the pellet trial.

**per 1,000 breeding ewes)

Table 9 Gross margins for goat scenarios with various assumptions on feed cost and value of goats.

Scenario	**Supplementary feed type**	**Gross margin $/hectare**				
		Lupins $250/tonne	**Lupins $450/tonne**	**Gross margin per hectare (original assumptions of lupins $350/tonne and goats $5.11/kg dressed weight**	**$3/kg dressed weight**	**$6/kg dressed weight**
Dirranbandi pellet trial (actual trial results)	No pellets	NA	NA	11.85	-0.50	17.08
Dirranbandi lupin trial (simulated*)	No lupins	NA	NA	11.12	-1.80	16.60
Dirranbandi lupin trial (simulated*)	Lupins	10.72	8.34	9.53	-3.50	16.74
Dirranbandi lupin trial (actual trial results)	Lupins	2.88	0.52	1.70	-10.80	7.00
Dirranbandi lupin trial (actual trial results)	No lupins	NA	NA	1.06	-9.02	10.10
Dirranbandi pellet trial (actual trial results)	Pellets	NA	NA	-1.58	-14.82	4.04

4.2.2 Economic optimisation

The optimisation of the gross margin calculator supports the previous reported result, namely that during the early commercial pellet trial it is uneconomic to supplement the goats feed intake. However, for the later lupin trial then it was economic to supplement the goats feed intake at the maximum rate. This conclusion was robust to variation in the structure of Model 2.

In both scenarios (un-supplemented early trial and high lupin feed rate in the late trial), it was economic to maximise the stay of animals to 180 days. This result was strongly influenced by the Warwick trials where there was a positive and increasing growth rate to be observed between 120 and 180 days, for both the pellet and lupin trials. Consequently, the positive gross margins kept increasing with the growth rate.

In this sense, for the initial live-weights considered (say between 12 and 18kg), and for the range of weights of goats in the study, duration of stocking should be longer than that evident in this study. That is, producers in Eulo, Dirranbandi and Kingaroy would have made more money had goats been stocked for longer.

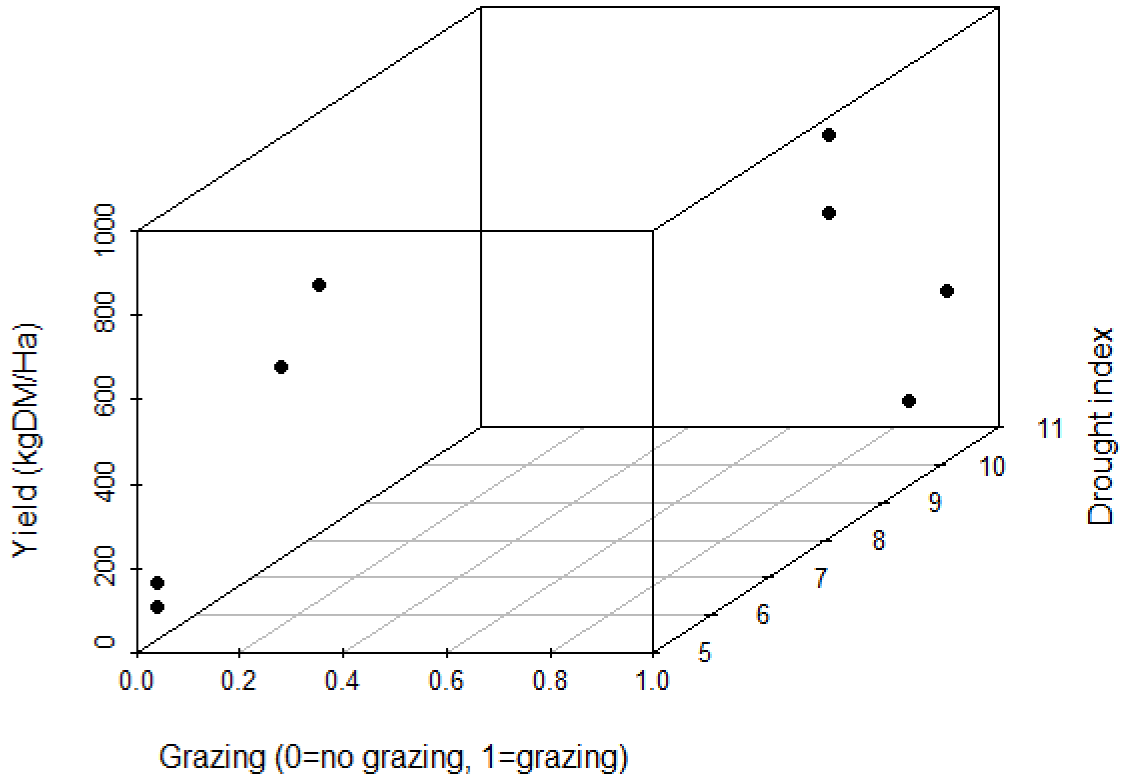
4.3 Goat influence on rangeland conditions

The median yield (kg of dry matter per hectare) was 294kg/ha before grazing commenced and 589kg/ha after grazing. See Table 10. There did not appear to be an association between grazing or drought index and yield (see Table 10).

Table 10: The yield (kilograms of dry matter per hectare) in paddocks before grazing with goats in the trial and after grazing by goats in the trial. Note: Many confounders remain uncontrolled in this comparison, such as prior grazing history.

Status of paddock	Yield (kg DM/ha)	Drought index (Keetch et al., 1968)
Prior to goat grazing in trial	294 (Q1:Q3: 120, 488)	6 (5-8)
Grazed by goats 6 months before (2016/2017)	589 (Q1:Q3: 353, 820)	9 (8-10)

Figure 5: The three-dimensional relationship between pasture yield and both drought index and goat grazing. There is no apparent relationship between yield and grazing or drought index.



The kilograms of dry matter per hectare was not associated with goat grazing in our analysis (p = 0.86). See Table 11.

Table 11: The model coefficients from a linear mixed model relating pasture yield to grazing (presence or absence) and drought index.

Model term (coefficient)	**Exp(Estimate)**	**Standard Error**	**T-value**	**Probability**
Intercept	41.3016	1.8792	1.9800	0.1421
Grazing (no grazing cf. grazing)	1.1838	0.8875	0.1900	0.8614
Drought index	1.2963	0.2773	0.9355	0.4185

Table 12: Random effects of the Yield model. Variability in the site is much lower than the residual variance.

Groups	Variance	Standard Deviation
Site	2.137×10^{-15}	4.623×10^{-8}
Residual	7.437×10^{-1}	8.624×10^{-1}

4.4 Extension activities

Several extension activities were conducted:

- Webinar

An MLA sponsored webinar was held on the 12/12/2017 on initial results of the pellet feeding.

- Articles

Three goats on the move articles were produced, including one associated with this report.

- Field day

A field day at Warwick was held on the 2/12/2017. The focus was on several topics including nutrition, goat health, equipment, pasture assessment and pellet feeding results.

Two further items are planned:

- A scientific manuscript will be considered when reporting is accepted.
- A possible further webinar

A further field day was planned at the Kingaroy site was planned but has been delayed indefinitely by maternity leave for Emma Berghofer. The planned webinar will occur in lieu and excess funds (for travel) have been removed from Ausvet's invoicing.

5 Discussion

5.1 Growth rates and effects of supplementary feeding

The effect of supplementary feeding was to markedly increase growth rates in supplemented goats compared with un-supplemented goats. As expected this was especially true when conditions were drier and less favourable. For example, during 2017/2018, supplementing goats with lupins during dry conditions resulted in growth rates of 70g/day, compared with growth rates of 32g/day for un-supplemented goats on similar pasture.

Overall, the greatest growth rates were obtained during 2016/2017 when conditions were more favourable. Under these circumstances, goats on pellets grew at 92g/day, and un-supplemented goats grew at 81g/day. Examining the international literature for comparisons it is evident there is little data on rangeland goat growth rates. However, Lu (2001) reviewed Boer goat and crosses for growth rates. He found that Boer goats grew at approximately 200g/day, dairy goats grew at 115g/day, Spanish cross Boer goats grew at 154g/day and Boer cross Angora goats grew at 161g/day. These results were generated using high concentrate diets. Other researchers have reviewed goat growth rates in continental Africa and concluded that goats grow at 30-75g/day from ages 3-12 months of age (Charles, Undated). The highest growth rates in the current study exceeded that growth rate (approaching 100g/day), suggesting that goat growth rates for rangeland goats were very high in the current study.

It is not possible to determine the genetic growth potential of goats in this trial design as stated in the design document (Alemseged & Atkinson, 2015a). For example, the trial provided pasture and some supplementary feeding, but was not a perfect diet with unlimited energy and therefore goats will not have grown at their full genetic potential. In addition, other factors such as disease and parasites, whilst well controlled in the trial were also present and tend to limit production. Despite this, conditions were favourable in 2016/2017 with well-designed goat production protocols (health management and parasite controls, a well-balanced entire supplement and good pasture and browse). Thus, the growth rates may be near the genetic potential, especially at Dirranbandi in 2016/2017.

It is important to note that most goat producers sold goats after they had been included in the trial for 3-6 months. Frequently, the sale time was dictated by available feed and drought. However, it appears that in some circumstances (except for Warwick), goats were still growing when sold and may have been profitably kept for longer. This can be observed on Figure 2 where growth curves are still increasing.

5.2 Gross margin analysis and comparison with other enterprises

Under most scenarios where goats were grown, gross margin analysis revealed it was less profitable to feed supplementary feed than it was to only graze goats (without supplementary feed) in a good season. For example, the highest gross margins of approximately $11-12 per hectare, or $44,000-48,000 profit per 1,000 goats were the un-supplemented goats (control goats). This indicates that to maximise profit, supplementary feeding should generally be avoided where possible in good season, although a case by case basis considering for example feed costs and goat market value should be made.

Despite this, where extremely poor conditions prevail, it is still possible to make more profit by supplementary feeding goats compared with un-supplemented goats. For example, the scenario where goats were fed lupins during drought conditions resulted in a gross margin of $1.70/hectare. This is fortunate as it is sometimes necessary to feed goats for reasons other than immediate profit (e.g. animal welfare), and it is useful to see that under adverse drought conditions, profit is still possible. In addition, supplementary feeding can allow goats to be sold earlier, allowing decreased stocking rates to benefit residual livestock. During that trial, conditions were very poor with goats growing 32g/day on un-supplemented pasture where there was as little as 2% green material at some sites (e.g. Dirranbandi) when stocking for the second season began.

The reduced gross margins when supplementing goats was largely due to the expense of purchasing lupins. Lupins cost $350/tonne. As the price of the supplementary feeds drops, the gross margin increases.

The gross margin analysis revealed that un-supplemented goats are quite profitable in comparison with other enterprises. For example, in comparison to other enterprises such as self-replacing Merino and Dorper flocks, goats achieved similar gross margins on a per hectare basis.

It is important to realise that the gross margin analyses explicitly included the cost of purchasing young 10-15 kg goats but did not include the cost of replacement Merinos and Dorpers. This was because young goats have a financial value and many producers purchase them to grow out. That is, there is a market for young goats, for example at saleyards in Australia. In comparison, replacement Dorpers and Merino are bred inexpensively on the property where the enterprise is based. However, this may mean the gross margin comparison between Dorpers and Merinos is weighted against goats. This is especially true when it is apparent that some producers supplement their enterprise (e.g. a mixed farming enterprise with Merinos and cropping) with inexpensively locally harvested rangeland goats that only incur a mustering expense from the 'back' paddock. In this case, these producers may very profitably raise young goats, but they have still forgone a sale of young goats before they were grown out, hence the inclusion of the cost of young goats in the gross margin analysis.

In addition, it is important to consider that gross margin analyses do not always reveal the full economic picture. That is, the gross margin tool approach is quite a crude and focused instrument and cannot account for several important economic factors when comparing rangeland goats with other enterprises. For example, these unconsidered factors include:

- Land and pasture resource used for producing goats.

Anecdotally, the land used to produce goats is often marginal country such as hilly and under-utilised paddocks on a property and hence of less value than land required for other enterprises. This would tend to allow more profitable goat enterprises as the cost of land is less expensive, or land is under-utilised.

- Goats also tend to be browsers as well as grazers and to consume a wide variety of plant species.

This allows them to utilise more available plant material (e.g. shrubs etc.) on a landscape, thus surviving drought conditions more easily than other grazing species such as sheep or cattle.

- Goats are also used to manage weeds in Australia (Peirce, 1991) and therefore have an additional economic benefit.

A more holistic economic tool such as cost benefit analyses would be required to address these larger property wide questions. This was beyond the scope of this study.

5.3 Goat influence on rangeland conditions

Clearly, grazing by all herbivores can affect rangeland conditions. For example, competition and land degradation by unmanaged goats has been listed as a key threatening process with a national threat abatement plan developed (Anon, 2008). The question is, what impact closely managed goat populations can have on rangeland conditions? Whilst this project found no association between some rangeland condition metrics (e.g. dry matter yield) and goat grazing, it's not felt the question was adequately addressed with the study design and sample size available. For example, the time frame of the study was too short to assess land condition changes, the data collection methods were inaccurate (e.g. could not quantify species composition on very short pastures evident at some sites), several confounding factors remained un-measured (e.g. prior grazing history) and the power of the study was too low (e.g. 4 properties were available when 20-30 would be required). Generally, the study was focused on assessing growth response to supplementary feeding and not assessing changes in rangeland conditions.

Assessing the influence of goat grazing on rangeland conditions would ideally take an alternative study design that would assess how pasture species composition and soil degradation changes over an extended period. This would require exclusion plots/control plots where no goat grazing occurred, to be compared with long term grazing areas. An additional design maybe an observational study that contrasts various goat stocking densities (including no grazing) and land condition. This could be like the current study but would require a much larger sample size (e.g. 20-30 properties and not the 4 properties that we used). Therefore, although the impact of goat grazing was addressed on some limited land condition metrics, the information available from this study to assess this objective was limited.

5.4 Improvements and changes to project delivery

5.4.1 Additional components beyond the initial study design

The project delivered several additional components, beyond the agreed project plan and/or contract. These included:

- Additional gross margin analysis

The original proposal stated that the goat data would be compared with a self-replacing Dorper enterprise. After requests by MLA, Ausvet agreed to include other common regional enterprises. Subsequently a self-replacing Merino sheep enterprise was included. This was done within the original budget.

- An additional years data

The original proposal was to follow goats for 12 months which was not practical for producers. Subsequently data collection continued for two years, although goats were not stocked continuously on each property for 2 years. This increased the complexity of managing the project.

- Two supplementary feeds assessed

The project assessed both a manufactured pellet and lupins. The use of a manufactured pellet was required for several reasons, but especially to ensure that the project was able to get as close as possible to assessing the genetic growth potential of goats. That is, to assess the genetic growth potential, feed needed to be balanced in terms of nutrients, energy, protein etc. This was only achievable with a manufactured pellet. Lupins assessment was also required to assess a less expensive, but less balanced supplementary feed and whether this could also achieve good and economic growth.

5.4.2 Components deleted from the original study proposal

Some components of the original study design were not pursued. These included:

- Sample size

Our sample size of paddocks was smaller than recommended in the original study design. Whilst the project started with five study sites (only four were stated in the TOR) one site was not able to comply with the study protocol. On average, only two paddocks were used per site instead of the four recommended, although additional paddocks were used, but destocked due to drought. Despite this, 2 replicates were used of goats on each property and paddock to double the sample size, that is the study was repeated twice.

So overall, the sample size was slightly smaller than recommended in Alemseged and Atkinson (2015a) (1,088 verse 1,200 goats). Despite this, the study achieved sufficient power, thereby using less animals to achieve the study aims, and thereby achieving better research animal ethics.

5.5 Future research

There are several areas where this project could be usefully extended to enhance goat meat production. These include:

a. Better assessment of the financial benefit of goat production

There are several additional benefits of goat production beyond other enterprises. This includes weed control, utilisation of sub-optimal pasture resources and management of the environmental impacts of unmanaged goat populations. In addition, many producers have un-managed goats on their property. A broader economic tool such as cost benefit analyses may allow assessment of the relative benefit of goats compared with the gross margin analysis conducted in this analysis.

b. Segregation trials

The data demonstrates that males grew faster than females. Further trials examining the growth rates of castrated and uncastrated males or the effect of segregating males and females maybe useful. For example, do females grow better when they are segregated from males?

c. Improved genetics

The growth rates achieved of nearly 91g/day were achieved under good conditions (good quality pasture and pellet supplementary feed) and maybe close to the genetic potential of rangeland goats. However, these growth rates are well below growth rates of Boer goats and crosses in the literature (albeit achieved with concentrate feeding) (Lu, 2001), but higher than African goats on pasture and browse. Whilst the comparison is not perfect (e.g. rangeland pasture fed goats cf. penned concentrate fed goats or African goats), this indicates that the genetic potential of rangeland goats maybe relatively low compared with Boer goats (Charles, Undated). Further research on improving growth rates through genetic improvement maybe warranted. This may include literature reviews, pen trials and field trials to examine the effect of cross breeding with Boer goats or simply genetic selection of rangeland goats to produce improved bucks for use in breeding programs.

d. Goat health

It was clear that there is increasing interest in goat production in eastern high rainfall sites, as indicated by the attendance at the field day (27 producers) and due to the availability of sites for the trial. However, experience shows that these sites present some goat health challenges, especially associated with internal parasites (e.g. coccidiosis, worms etc.) and their impact on goats. Paradigms of parasite management are rapidly evolving and animal health professional knowledge of goat health is low. Research (literature reviews, field research), assistance to register goat anthelmintics and extension work would assist high rainfall/smaller property goat health and production.

e. Best practice management of goats to maintain rangeland condition

Like other species of livestock, goats may damage rangeland condition when poorly managed. However, it is difficult to judge the best management strategies to maintain rangeland productivity and health. Further research is indicated as the study design was not suitable to assess this question in the current study.

6 Conclusions/recommendations

Under the trial conditions it was clear that supplementary feeding of goats could lead to profitable production at an enterprise level under some circumstances. That is, when the season was poor (drought), and carcass weight returns were $5.11/kg of carcass weight, and lupins cost $350/tonne it was more profitable to supplementary feed growing goats than to rely only on pasture. Supplementary feeding also has additional benefits, that goats can be marketed earlier, thereby reducing grazing pressure and benefiting residual livestock.

Alternatively, when the season was good, it was clear that supplementary feeding of goats was less profitable than only relying on pasture. That is, when the season was good (abundant pasture) and carcass weight returns were $5.11/kg of carcass weight, and pellets cost $660/tonne the gross margin declined when supplementary feeding was used. Assuming similar growth for goats on pellets and lupins, this finding also held in good years if less expensive lupins at $350/tonne were used.

Growth rates in rangeland goats approached 100g/day under good pastoral conditions with supplementary feed.

Goat gross margins per hectare were comparable to other enterprises such as Dorper and Merino self-replacing flocks. As gross margin analyses are narrowly focused, the relative benefit may even be greater, if for example goats can be produced as an additional enterprise on a property by using under-utilised lower quality paddocks that are suitable for goats, or to also control weeds. It is thus recommended that western mixed farming and Merino producers consider incorporating a goat growing enterprise to enhance whole farm profitability.

7 Key messages

Supplementary feeding of rangeland goats can be profitable during drought conditions and allows stock to reach their sale weights earlier, thus ensuring more feed for the remaining herd.

Supplementary feeding should be generally avoided when conditions are reasonable. However, each situation needs to be assessed on its merits. For example, feed would need to be cheap and goat prices would need to be very good to make supplementary feeding profitable during good seasons.

Both pellets and lupins were highly desirable to goats, consumed readily and led to weight gains. Lupins were much less expensive. Pellets flowed more easily in feeders than chopped lupins which tended to block feed shutes. Whole lupins are therefore preferable to chopped lupins.

Growth rates of +80 g/day are possible in un-supplemented goats when conditions are favourable.

Males grow faster than females.

Growing out underweight goats is as profitable as Merino and Dorper self-replacing flocks on per hectare basis. In addition, goats have some additional benefits such as weed control and allow utilisation of less optimal pasture. Growing goats should be considered as an additional profitable enterprise in the rangelands.

Goat health in higher rainfall conditions can be compromised at high stocking densities by internal parasites. Great care is required to manage parasites.

8 Bibliography

Alemseged, Y. (2015). *Determination of Dorper DSE rating for stocking decisions*. Meat and Livestock Australia Sydney, Australia Retrieved from https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Environment-On-Farm/Determination-of-Dorper-DSE-rating-for-stocking-decisions/3102

Alemseged, Y., & Atkinson, T. . (2015a). *Trial design development to determine expected growth rates of young goats. Final report for MLA Project Number B.GOA.0109*. Sydney, Australia Meat and Livestock Australia

Alemseged, Y., & Atkinson, T. . (2015b). *Trial design development to determine expected growth rates of young goats: Appendix 1 – Factors affecting growth in goats: Review of literature. Appendix to Final report for MLA Project Number B.GOA.0109.* Sydney, Australia Meat and Livestock Australia.

Alexander, M.E. . (1990). Computer calculation of the Keetch-Byram Drought Index-programmers beware. *Fire Management Notes, 51*(4), 23-35.

Anon. (2008). *Competition and land degradation by unmanaged goats*. Canberra Australian Government Retrieved from http://www.environment.gov.au/biodiversity/threatened/publications/tap/competition-and-land-degradation-unmanaged-goats.

Anon. (2017). *Livestock gross margin budgets October 2017*. Orange, NSW, Australia New South Wales Government Retrieved from https://www.dpi.nsw.gov.au/agriculture/budgets/livestock.

Anon. (2018). Making more from sheep. Retrieved 4 September, 2018, from http://www.makingmorefromsheep.com.au/efficient-pastoral-production/tool_12.14.htm

Araya, J., Bedos, M., Duarte, G., Hernandez, H., Keller, M., Chemineau, P., & Delgadillo, J. A. (2017). Maintaining bucks over 35 days after a male effect improves pregnancy rate in goats. *Animal Production Science, 57*(10), 2066-2071. doi: 10.1071/an16194

Brooks, Mollie E., Kristensen, Kasper, van Benthem, Koen J., Magnusson, Arni, Berg, Casper W., Nielsen, Anders, . . . Bolker, Benjamin M. (2017). Modeling Zero-Inflated Count Data With glmmTMB. *bioRxiv*. doi: 10.1101/132753

Charles, A.B. (Undated). *Factors affecting the growth of sheep and goats in Africa*. Italy: Food and Agriculture Organisation Retrieved from http://www.fao.org/wairdocs/ILRI/x5464B/x5464b0a.htm.

Keetch, J.J, Byram, G.M., & eorge M. . Res. Pap. SE-38. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 35 p. (1968). *A Drought Index for Forest Fire Control*. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest

Lu, C. (2001). *Boer goat production: progress and perspective.* Paper presented at the Proceedings of International Conference on Boer Goats, Anshun, China.

Magnusson, A. , Skaug, H.J., Nielsen, A. , Berg, C.W. , Kristensen, K. , Maechler, M. , . . . Brooks, M.E. (2017). *glmmTMB: Generalized Linear Mixed Models using Template Model Builder*. Austria R Core Team Retrieved from https://github.com/glmmTMB.

McDonald, W., & Orchard, P. (2018). Using DSEs and carrying capacities to compare sheep enterprises. Retrieved 4 September, 2018, 2018, from https://www.dpi.nsw.gov.au/agriculture/budgets/livestock/sheep-gross-margins-october-2015/background/dse

Parkes, J., Henzell, R., & Pickles, G. (1995). *MANAGING VERTEBRATE PESTS: FERAL GOATS*. Canberra: Australian Government Publishing Services.

Peirce, J. (1991). *Using goats to control weeds*. Perth Western Australian Government.

R_Core_Team. (2018). A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/.

Tothill, J. C., Hargreaves, John, & Jones, Rm. (1992). *BOTANAL-A comprehensive sampling andcomputing procedure for estimating pasture yield and composition. 1. Field sampling* (Vol. 78).

9 Appendix 1: Trial design document.

B.GOA.0109_Approved_Trial_Design_APPENDIX_8.2.pdf

10 Appendix 2: Feed analysis of pellet

Goat Supplement Pellet V2.pdf

11 Appendix 3: Feed analysis of lupins

LupinAnalysis_566560-A-[R00].pdf

12 Appendix 4: R code

Microsoft Word 97
- 2003 Document

13 Appendix 5: Gross margin spreadsheet calculator

Copy of Enterprise
GM Comparisons_S\

14 Appendix 6: Model coefficients for models 1-3